THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. I.—*Contributions to Meteorology;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Twenty-first paper. With plate I.

[Read before the National Academy of Sciences, April 21, 1885.]

Direction and velocity of movement of areas of low pressure.

IN several former papers I have examined the direction and velocity of movement of areas of low pressure. Since those papers were written, the materials for these investigations have been greatly multiplied, and I now present a summary of the results which I have obtained after an extended examination of the Signal Service observations, and of the observations made in other parts of the world.

The monthly maps of storm tracks, which are issued by the Signal Service in connection with the International Bulletin, give a distinct idea of the general direction of movement of areas of low pressure for all parts of the Northern hemisphere. Plate I was formed by a combination of these monthly maps for several years. It represents only a small part of the storm tracks delineated on the monthly maps, and does not attempt to represent the storm tracks of different regions in their relative frequency, but it is designed to afford a specimen of all the important storm tracks delineated on the monthly maps for all parts of the Northern hemisphere.

From this chart we see, that north of the parallel of 30 degrees, storm tracks in all longitudes almost invariably pursue an easterly course, but generally they show an inclination toward the north of east; while within the tropics, storm tracks almost invariably tend westerly, with an inclination toward the north of west. We also notice that none of the storm tracks reach down to the equator. The lowest latitude of any centre of low pressure which has been distinctly traced is 6·1° N., and there are eight cases of cyclonic storms whose paths have been traced to points south of lat. 10° N. Hard gales and violent squalls of wind sometimes occur directly under the equator, accompanied by sudden oscillations of the barometer; but within six degrees of the equator, the depression of the barometer has never been found sufficiently great, and the depression has not been maintained with sufficient steadiness, to enable us to identify an area of low pressure in its progress from day to day.

The tropical cyclones which have been found to pursue a westerly course are limited to two districts. 1. The Atlantic Ocean, and chiefly its western part near the West India Islands; and 2. the region south of the continent of Asia. Tropical cyclones have never been observed in any part of the Pacific Ocean, with the exception of its western portion near the continent of Asia and the neighboring islands. In my fifth paper I gave a table showing the leading particulars respecting the most violent cyclones originating near the West India Islands, whose paths had been investigated previous to 1875; and in my fourteenth paper I gave a similar table based on the observations contained in the International Bulletin. The average course of the cyclones enumerated in my fifth paper, while they were moving westward, was 26 degrees north of west; and the average course of those enumerated in my fourteenth paper, during the same part of their course, was 26½ degrees north of west.

According to Maury's Pilot charts of the North Atlantic, the average direction of the wind for that part of the Atlantic Ocean in which these cyclones most frequently occurred during the three months, August, September and October (which months include nearly all the cyclones referred to), is two degrees north of east. According to the charts of the United States Hydrographic Office, which include all the observations collected by Maury and also those collected by the British Meteorological Office, the average direction of the wind is 4½ degrees north of east. The average course of West India cyclones, while moving westward, differs therefore from 28 to 30 degrees from the average course of the wind. But if we make a comparison of the winds immediately succeeding each

of the cyclones and continuing for at least 24 hours, we find that the direction of a cyclone's progress accords more nearly with the direction of the principal wind which prevails at the time of the cyclone.

The average course of the cyclones originating near the China Sea and Bay of Bengal, as enumerated in my fourteenth paper, was 38 degrees north of west, as long as they were moving westerly. The average course of the Asiatic cyclones indicated by the maps accompanying the International Bulletin (nearly all of which originated in the China Sea), was 27½ degrees north of west. Since the average direction of the wind in this region changes nearly 180 degrees from summer to winter, in order to make a satisfactory comparison between the average direction of the wind and that of the progress of storms, we must make a separate comparison for the different seasons of the year. Since nearly all the cyclones, whose tracks are shown on the International charts, originated in the China Sea, I will make the comparison for this region; and since nearly all of these storms occurred from July to November, I will make the comparison for these months.

According to Maury's Pilot Chart of the China Sea, the average direction of the winds in this sea for the month of July is south 22° west; for August it is south 39° west, and for September it is south 39° west. The average for these three months is south 33° west. The average direction of the wind for October is north 53° east, and for November it is north 41° east. The average for these two months is north 47° east. For the first three months, the average direction of progress of storms, is 35° north of west, and for the last two months it is 25½° north of west; that is during the first period the average course of storms differs 88 degrees from the average direction of the wind, and during the last period the difference is 68½ degrees. We also perceive that a change of 166 degrees in the average direction of the wind is accompanied by a change of only 9½ degrees in the average direction of the progress of storms. This fact clearly indicates that the direction in which storms advance is mainly determined by some other cause than the mean direction of the wind. If, however, we make a comparison with the winds immediately succeeding each of the cyclones, and continuing for at least 24 hours, we shall find that the direction of progress of a cyclone corresponds more nearly to that of the principal wind prevailing at the time of the cyclone. It is not, however, claimed that there is an exact agreement between these two directions.

An examination of the accompanying plate shows that in the middle latitudes of the Northern hemisphere there is a remarkable correspondence between the average direction of the

progress of storm centers, and the average direction of the wind as shown by Coffin's wind charts. I have endeavored to ascertain whether this correspondence is exact, or whether there is a constant difference between these two directions. I first made a comparison of these two directions for the Atlantic Ocean.

In order to determine the average direction of progress of storm centers across the Atlantic Ocean, I measured with a protractor the bearing of the storm tracks delineated on the U. S. International charts. These bearings were measured for six points, viz: at the intersection of the storm tracks with the meridians of 10°, 20°, 30°, 40°, 50° and 60° west of Greenwich, and the measurements included the observations of four years, viz: 1878–1881. The following table shows the average results of these measurements for each month of the year, and for each of the six points above mentioned. The latitudes named at the top of the table are the average latitudes corresponding to the given directions.

Average direction of Storm tracks.

	Long. 60°. Lat. 46·9°.	Long. 50°. Lat. 48 9°.	Long. 40°. Lat. 51·8°.	Long. 30°. Lat. 53·9°.	Long. 20°. Lat. 54·9°.	Long. 10°. Lat. 55·5°.
January	N. 66° E.	N. 61° E.	N. 64° E.	N. 74° E.	N. 86° E.	N. 96° E.
February	66	67	60	60	74	82
March	73	69	68	65	71	79
April	63	68	72	79	91	97
May	62	67	68	71	76	76
June	76	63	64	67	71	71
July	72	62	59	68	76	80
August	69	74	74	77	72	71
September	67	72	78	75	75	73
October	67	64	72	68	73	72
November	70	67	62	69	68	69
December	65	66	62	67	73	80
Year	N. 68 E.	N. 67 E.	N. 67 E.	N. 70 E.	N. 75 E.	N. 79 E.

I have determined the average direction of the wind at several points on the Atlantic Ocean, as near as possible to the points corresponding to the preceding measurements. I have determined the directions according to Maury's Pilot Charts, and also according to the charts of the U. S. Hydrographic Office. Since the latter charts are based on the greatest number of observations, I have used them in the comparisons exhibited in the following table. The wind directions here given are deduced from the observations for January, April, July and October. Along the line of the storm tracks, the number of wind observations on the charts is very small, and I have therefore deduced the wind directions from the observations in the five degree squares a little south of the average storm tracks.

Comparison of Storm tracks with Wind directions, over the Atlantic Ocean.

Longitude.	Latitude of storm tracks.	Direction of storm tracks.	Latitude of wind directions.	Direction of wind.	Difference of latitude.	Wind most northerly.
60°	46·9°	N. 67·0° E.	42·5°	N. 79·3° W.	4·4°	−33·7°
50	48·9	63·7	42·5	S. 85·2 W.	6·4	−21·5
40	51·3	66 7	47·5	S. 61·6 W.	3·8	+ 5·1
30	53·9	72·2	47·5	S. 73·5 W.	6·4	− 1·3
20	54·9	81·5	50·0	S. 65·2 W.	4·9	+16·3
10	55·5	86·2	52·5	S. 58·6 W.	3·0	+27·6

Column 1st shows the longitudes for which the comparisons are made; column 2d shows the latitude of the points to which the direction of the storm tracks corresponds; column 3d shows the average direction of the storm tracks for the months of January, April, July, and October; column 4th shows the latitudes corresponding to the wind directions; column 5th shows the direction of the wind for the given latitudes and longitudes; column 6th shows the differences of latitude between the points to which the storm tracks correspond, and those to which the wind directions correspond; column 7th shows the difference between the average direction of the wind, and the average direction of the storm paths for the points of comparison.

It will be seen that there is an average difference of nearly five degrees between the latitudes of the points for which the wind directions are given, and those to which the storm tracks correspond. I have endeavored to determine the proper correction of the wind directions for this difference of latitude, but the corrections appear so questionable that I have made no use of them.

We see that for the middle of the Atlantic Ocean near the parallel of 50° the average direction of storm paths corresponds very closely with that of the average progress of the wind; but in the western part of the Atlantic, the average course of storms is 30 degrees more northerly than that of the wind, while in the eastern part it is nearly 30 degrees more southerly.

I next made a similar comparison for twelve of the Signal Service stations in the northwestern part of the United States, between the Rocky Mountains and the meridian of 90° from Greenwich, for the three winter months for the ten years from 1873 to 1882. The wind directions were deduced from the sum of the observations for each of the eight principal points of the compass and the direction of the storm paths on the Signal Service maps was measured with a protractor. The following table shows the result of this comparison. Column 2d shows for each of the stations the mean direction of the wind; column 3d shows the average direction of the storm paths; and

column 4th shows the difference between these two directions. The directions are all measured from the north point toward the east.

Comparison of storm paths with wind directions, United States.

	Wind blows towards	Storms move towards	Storms most northerly.
Bismark	N. 162·7° E.	N. 107·7° E.	+55·0°
Ft. Sully	154·2	106·7	47·5
Breckenridge	126·2	105·5	20·7
North Platte	121·0	104·1	16·9
Keokuk	104·7	88·3	16·4
Yankton	121·6	106·3	15·3
Omaha	114·7	100·8	13·9
Davenport	96·8	87·0	9·8
Dubuque	92·7	88·3	+ 4·4
St. Paul	78·0	99·3	−21·3
LaCrosse	67·1	90·5	−23·4
Pembina	85·7	109·4	−23·7

We see that at all of the stations, except the last three, the average wind of winter blows toward a point somewhat south of east, and for four of the more western stations, the average direction is 51° south of east. We also see that at the more western stations, the average movement of storm centers is toward a point considerably south of east, but at the more eastern stations the direction is a little north of east. At Bismark and Fort Sully, the average course of the winds is 50° more southerly than that of storm paths, while at St. Paul, La Crosse and Pembina it is 22° more northerly.

The facts here stated afford a basis for some general conclusions respecting the movement of storm centers. Some meteorologists have claimed that the progressive movement of storm areas is satisfactorily explained by saying that they are carried forward by the general movement of the mass of the atmosphere within which they are formed; that is, they *drift* in a sense similar to that in which waves, eddies, etc., formed on the surface of a river, drift with the current. They advance as the water of the river advances, and in the same direction. But we have found that the average direction of movement of areas of low barometer does not generally coincide with the average direction of the wind for the same region. This is seen not only in the case of tropical storms, but also in storms of the middle latitudes.

But it may be claimed that the progress of storm areas is not determined entirely by the average movement of the atmosphere, but by that movement which is taking place at the date of the storm. There is some reason to think that in the case of tropical cyclones, particularly in the China Sea, the wind which generally prevails at the time of the cyclone accords more

nearly with the direction of the storm's progress, than does the average wind for the same season of the year; but there is no evidence that there is an exact agreement between these two directions. If we claim that the progressive movement of a storm area is due to the progressive movement of the general mass of the atmosphere in which it is formed, it seems necessary to admit that a mass of the atmosphere, of considerably greater extent than the storm area, is advancing in the same direction and at the same rate as the storm advances. In order to decide whether such is the fact, we need only to consult a well-constructed weather map, of sufficient dimensions to include not merely a storm area, but a considerable margin beyond it. The storm maps which have accompanied my former papers are too limited to furnish the required information in a form which is entirely satisfactory, and it is desirable to have similar maps for several successive days. The Signal Service maps afford abundant materials for this purpose, and Hoffmeyer's maps are still better, since they include a much larger portion of the earth's surface. If we open a volume of these maps anywhere at random, we shall not find the general mass of the atmosphere surrounding a great storm moving forward in the same direction as that in which the storm advances.

If we follow the progressive movement of a great storm from day to day, by means of maps representing the phenomena at intervals not greater than eight hours, we shall find that in front of the storm the air appears to be drawn in toward the center, by which means the pressure on the front side of the storm is diminished. The air, thus drawn in toward the center, rises to a considerable elevation above the surface of the earth and its vapor is condensed. In the rear of the storm, the exterior air rushes in and restores the pressure on that side; and as the result of this double process, the point of least barometric pressure is carried forward. This movement of the exterior air in the rear of a storm, is not necessarily in the same direction as that in which the storm center advances. In the United States, storms almost invariably advance eastward, and generally toward a point a little north of east; but the wind which presses upon the rear generally comes from the north or northwest, which direction is often at right angles, or nearly at right angles, with the direction in which the storm center advances. This movement of the air, by which the center of least pressure is carried forward, bears some analogy to the movements which cause the advance of a wave upon the surface of the ocean, and hence we may with propriety say that the progressive movement of a storm area, is the movement of a great atmospheric *wave*.

Besides these general considerations, there are various special

phenomena which indicate that the movement of areas of low pressure cannot be fully explained by the theory of a general drift of the atmosphere. We frequently find two neighboring low areas advancing in directions inclined to each other at an angle of 45 degrees, or even a greater angle. In the United States, while a low center is advancing from Florida along the Atlantic coast toward the northeast, another low center may be advancing eastward over the region of the Great Lakes, and the two low centers may coalesce somewhere in the neighborhood of Nova Scotia or Newfoundland. It will be seen from the accompanying plate, that the storms which proceed from the Gulf of Mexico and from the neighborhood of the West India Islands, generally advance toward Newfoundland; and the storms which come from the northwestern part of the United States, also tend toward the same region. Newfoundland becomes thus a point of convergence of storm tracks proceeding from regions quite remote from each other. In the vicinity of Newfoundland, there exists some influence which appears to act as an attractive force upon storm centers. This influence probably results from the great amount of precipitation near that island, arising from the proximity of the warm water of the Gulf Stream, to the colder air from the land. The accompanying plate shows other points toward which storm tracks seem to converge, particularly the Asiatic coast near Japan, and this fact probably results from a cause similar to the one just named. If the accompanying plate exhibited the storm tracks of different regions according to the relative frequency of their occurrence, other points of convergence of storm tracks would be exhibited. Along these converging storm paths, two storms often travel simultaneously and coalesce in a single storm area. Such a movement appears inconsistent with the drift theory.

For the convenience of those persons who may wish to investigate cases of this kind for themselves, I present the following list which shows some of the most decided cases in which two

Examples in which two centers of low pressure approach each other and coalesce.

1873.	March	29.1–29.2	1875.	Nov.	10.1–10.2	1879.	Jan.	1.3– 2.2
	Oct.	4.3– 5.1	1876.	March	25.3–26.1		Feb.	4.1– 4.2
	Oct.	11.1–11.3	1877.	Dec.	29.3–30.1		Oct.	16.1–17.1
1874.	April	19.2–19.3	1878.	Feb.	14.3–15.1		Oct.	28.2–28.3
	April	25.2–25.3		March	13.3–14.1		Nov.	20.1–20.2
	Aug.	30.2–31.1		May	2.1– 2.2	1880.	Feb.	13.1–13.2
	Sept.	25.1–25.3		June	18.1–18.2		March	7.2– 8.1
1875.	Jan.	22.2–22.3		Nov.	22.1–22.2		Oct.	29.2–29.3

centers of low pressure in the United States have coalesced. They are taken from the Signal Service Weather Maps for the

years 1873–1880. These maps show a considerable number of other cases of like kind, some of which have been omitted because the depression of the barometer was small; and others because the position of the low center was not very sharply defined, or was situated near the margin of the weather map.

Among these twenty-four cases, there are only three in which the paths of the two low centers were not inclined to each other at an angle as great as 45°; in half of the cases the two paths were inclined at an angle considerably greater than 45°; in eight or nine of the cases the angle was nearly as great as 90°; and in three of the cases the angle was greater than 90°.

It sometimes happens that within an area of low pressure, having but a single center, a second low center is developed. The following list shows twenty-four such cases, selected from the Signal Service maps for 1873–1880. The maps show a large number of other similar cases, but in the cases here cited the depression of the barometer was generally considerable, and the position of the low centers was distinctly indicated.

Cases in which a second low center is developed within an area of low pressure.

1873.	Feb.	18.1–18.2	1875.	Jan.	30.3–31.2	1878.	Jan.	13.2–13.3
	Feb.	20.1–20.2		May	4.2– 4.3		Jan.	30.2–31.1
	March	28.2–29.1		Nov.	3.1– 3.2		March	12.3–13.1
1874.	April	25.1–25.2	1876.	March	5.3– 6.1		Nov.	23.3–24.1
	Aug.	29.1–29.2		March	25.2–25.3	1879.	March	29.1–29.2
	Aug.	30.1–30.2		May	7.1– 7.2	1880.	Jan.	21.3–22.1
	Nov.	23.1–23.3		May	7.2– 7.3		Feb.	12.2–12.3
1875.	Jan.	24.2–24.3	1877.	Dec.	29.2–29.3		April	17.1–17.2

In a majority of these cases, the two low centers appear to have subsequently coalesced; but in several of them, the two low centers moved off in directions inclined to each other at an angle of 90° or more, and with unequal velocities.

Over the Atlantic Ocean and Europe, cases similar to the preceding are of much more frequent occurrence than in the United States; the depression of the barometer is generally much greater; and the low areas have a much greater geographical extent. By consulting Hoffmeyer's Weather Maps, we may easily find examples in which two low centers move toward each other from nearly opposite directions and coalesce; and we may also find frequent cases in which a great area of low pressure, with but one center, undergoes a change by which two low centers are developed, and these new low centers recede from each other. Sometimes there is a further change by which three or four or even more low centers are formed, and these low centers have a progressive movement in different directions, and with unequal velocities.

On the contrary, within a large area of low pressure, showing

several low centers, a low center may disappear from simple changes of pressure. In like manner a second low center may disappear and so on. In many cases the changes in the position and magnitude of the low centers are so rapid, that in comparing two weather maps for successive days, we frequently find it impossible to identify a low center on one of the maps, with its corresponding low center on the other map. Examples may be easily found to illustrate all of these different cases, so that it seems to be unneccessary to present a selected list. In cases like these, it surely will not be claimed that the movement of the low centers can be ascribed to a simple drifting of the general mass of the atmosphere in which the low areas were formed.

If we reject the drift theory, it will doubtless be asked how can we explain the fact that in the middle latitudes, storms almost invariably advance toward the east, and the opposite movement only occurs occasionally, and seldom continues longer than one or two days. This fact seems to result from the prevalent movement of the wind towards the east. The result however is not due to a general drifting of the mass of the atmosphere within which the low area is formed; but to the fact that the pressure on the west side of the low area is more steady and persistent than that on the east side. The characteristic features of a great storm movement are a motion of the air from all sides spirally inward, together with an upward movement resulting in the condensation of vapor at various places within the low area. Now if the air pressed in with equal force on all sides of the low center, and if there was an equal precipitation of vapor on all sides, there does not appear to be any reason why the low center should advance at all. It sometimes happens that the pressure on the west side is very small, while there is considerable pressure on the east side, and in such cases the low center moves toward the west. Many examples of this kind are shown by the Signal Service maps, and also by Hoffmeyer's charts. But this movement toward the west cannot be long maintained. In the middle latitudes, the east winds are exceptional, and result mainly from disturbances caused by storms. On the contrary, the west winds result from general causes which are permanent in their character, and are independent of storms; and if there were no storms the west winds would rarely be interrupted. During the prevalence of an east wind, the causes which produce west winds are not destroyed; their influence is only temporarily suspended; and they soon return with a force, not impaired, but rather augmented by their temporary suspension. The pressure on the west side of storm areas is thus a strong and persistent one, while that on the east side results from temporary causes, and

cannot be long maintained. It occasionally happens, during a violent storm, that the east winds are stronger than the west winds. In such a case the low center may be pushed westward; but such a result does not necessarily follow, for a large part of the air which pushes in on the east side rises from the earth's surface, while the air which pushes in on the west side does not rise at all, or not to an equal extent. Thus the low area is filled up on the west side, and were it not for the continued precipitation of vapor, the low area would soon become obliterated.

Rate of progress of areas of low pressure.

In order to exhibit the average velocity with which centers of low pressure advance over the United States, I have prepared the following table which shows, in miles per hour, the average velocity of storm centers for each month during a period of thirteen years, according to the observations of the United States Signal Service.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1872	31·2	29·4	34·5	34·5	24·7	21·8	24·6	18·3	22·2	20·9	23·6	28·8
1873	25·8	32·7	28·1	22·3	23·5	20·8	24·6	17·8	23·1	28·1	27·9	26·7
1874	23·0	33·9	29·8	31·4	22·2	22·4	25·9	19·9	23·1	28·5	30·3	32·7
1875	32·1	32·8	30·0	26·4	29·2	31·5	25·3	17·1	30·5	23·4	30·0	31·1
1876	38·1	31·5	26·4	23·6	24·7	19·3	26·4	23·2	23·8	27·7	22·6	38·3
1877	37·7	26·5	32·6	25·2	27·3	25·2	24·2	20·0	17·4	20·2	25·5	24·7
1878	26·3	27·7	24·3	22·6	17·9	18·4	21·7	26·8	23·9	19·6	21·2	34·0
1879	35·5	33·3	35·1	27·8	25·3	29·4	26·4	21·0	21·7	30·8	40·7	38·7
1880	37·6	39·6	35·8	27·2	25·1	24·5	25·7	25·9	23·5	22·3	34·1	38·8
1881	32·3	35·4	26·8	37·1	32·6	32·8	26·6	25·4	30·6	37·5	30·8	33·6
1882	42·1	41·6	34·8	29·5	21·6	26·8	19·8	19·9	23·5	27·7	27·7	30·2
1883	39·8	36·4	38·0	28·4	30·0	24·2	25·8	28·0	25·0	37·3	39·4	33·0
1884	38·6	43·9	33·3	21·5	26·8	20·5	22·4	30·7	32·6	34·4	35·2	43·7
Mean	33·8	34·2	31·5	27·5	25·5	24·4	24·6	22·6	24.7	27·6	29·9	33.4

We see from this table that the average velocity of progress of storms for the entire year is 28·4 miles; also that the velocity is greatest in February and least in August, and that the former velocity is 50 per cent greater than the latter. We also see that the velocity varies very much for the same month in different years, the greatest mean velocity for the months of April and October being more than double the least mean velocity for the same months.

In order to study the movement of areas of low pressure under the greatest possible variety of circumstances, I have endeavored to obtain information from European observations. In the Uebersicht der Witterung for 1881, published by the Deutsche Seewarte, is given a table showing the mean velocity of movement of the barometric minima for the five years 1876–80, as deduced from the monthly charts of storm tracks.

The following table shows the average results deduced from the observations of these five years.

Rate of progress of Storm Centers in Europe.

	Kilom. in 24 h.	Miles p. hour.	Storms. in U. S.	Ratio.		Kilom. in 24 h.	Miles p. hour.	Storms. in U. S.	Ratio.
January	673	17·4	33·8	1·94	July	549	14·2	24·6	1·63
February	694	18·0	34·2	1·90	August	541	14·0	22·6	1·41
March	676	17·5	31·5	1·80	September	667	17·3	24·7	1·47
April	626	16·2	27·5	1·70	October	732	19·0	27·6	1·53
May	569	14·7	25·5	1·73	November	720	18·6	29·9	1·60
June	609	15·8	24·4	1·54	December	693	17·9	33·4	1·87
					Year	646	16·7	28.2	1.69

Column 2nd shows the velocity of movement for each month expressed in kilometers for 24 hours; column 3d shows the velocity expressed in English miles per hour; column 4th shows the velocity of movement of storm centers for the United States; and column 5th shows the ratio of the numbers in columns 3 and 4.

We see that in the United States the average velocity of movement for the entire year is about two-thirds greater than it is in Europe. This ratio is greatest in winter when it amounts to 1·9; and least in the autumn when it amounts to 1·5.

The following table shows, in miles per hour, the average rate of progress of storm centers over the Atlantic Ocean, as deduced from the monthly charts of storm tracks published with the International Bulletin for a period of four years from 1879 to 1882.

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
17·4	19·5	19·7	19·4	16·6	17·5	15·8	16·3	17·2	18·7	20·0	18·3

The average velocity for the entire year is 18 miles per hour.

If now we compare the preceding results with those heretofore found for the West India cyclones while pursuing a westerly course, and for the cyclones of the Bay of Bengal and China Sea for the same part of their course, we shall have a view of the movement of storm areas under a great variety of conditions. If we compare the average results for these five districts for the entire year, the numbers are as follows:

United States	28·4	miles per hour.
Middle latitudes of Atlantic Ocean	18·0	" "
Europe	16·7	" "
West India cyclones	13·7	" "
Bay of Bengal and China Sea	8·4	" "

Thus we see that the average rate of progress of storm centers over the Atlantic Ocean is about the same as over Europe,

and is double the rate of progress for the China Sea; and the rate of progress for the United States is more than three times the rate for the China Sea. These results are derived from so large a number of observations, that they must be accepted as substantially correct, and they demand a clear explanation.

I have endeavored to determine how far these differences may result from a difference in the mean velocity of the wind for these several districts. For this purpose I determined the average velocity of the wind for that portion of the United States within which the storm centers are most frequently found, viz: that portion north of the parallel of 40°, and east of the meridian of 100° from Greenwich. A slight examination of the observations shows that at stations near the Atlantic Ocean, or near one of the Great Lakes, the velocity of the wind is greater than at stations in the interior of the country. I have therefore divided the observations into two groups, one including the stations near the ocean, or one of the Great Lakes, and called coast stations (twenty-five in number), the other group including the remaining stations, which are called inland stations (twenty in number); the second and third columns of the following table show, for each month of the year, the mean velocity of the wind in miles per hour for these two classes of stations, according to the Signal Service observations:

	Coast Sta.	Inland Sta.	Mean.	Storms.	Ratio.		Coast Sta.	Inland Sta.	Mean.	Storms.	Ratio.
Jan.	10·98	8·40	9·69	33·8	3·5	July	7·70	6·87	7·28	24·6	3·4
Feb.	11·33	8·94	10·13	34·2	3·4	Aug.	7·42	6·40	6·91	22·6	3·3
Mar.	11·76	10·18	10·97	31·5	2·9	Sept.	8·98	6·96	7·97	24·7	3·1
April	10·67	9·59	10·13	27·5	2·7	Oct.	9·96	7·84	8·90	27·6	3·1
May	9·22	8·55	8·88	25·5	2·9	Nov.	11·16	8·50	9·83	29·9	3·0
June	8·34	7·56	7·95	24·4	3·1	Dec.	11·30	8·20	9·75	33·4	3·4

The 4th column gives the mean between the numbers in the two preceding columns; the 5th column shows for each month the rate of progress of storm centers; and the 6th column shows the ratio of the velocity of storm centers to the mean velocity of the wind.

We see that this ratio is not the same for all months; but for that month in which the rate of progress of storms is greatest, the ratio is sensibly the same as for that month in which the rate is the least. This coincidence seems to indicate that the rate of progress of storms is in some degree dependent upon the mean velocity of the wind; but the considerable inequalities in the value of this ratio show that the rate of progress of storms cannot depend solely on the average velocity of the wind.

I next determined, as well as I was able with the means at my command, the average velocity of the wind for that part of

Europe within which storm centers are most frequently found, viz: between the parallels of 50 and 60 degrees. The following table shows the results which I have obtained, and the observations are divided into two groups as in the preceding table; the coast stations being twelve in number, and the inland stations being fourteen in number. The velocities are all expressed in miles per hour.

	Coast Sta.	Inland Sta.	Mean.	Storms.	Ratio.		Coast Sta.	Inland Sta.	Mean.	Storms.	Ratio.
Jan.	13·86	8·61	11·23	17·4	1·5	July	11·52	6·53	9·02	14·2	1·6
Feb.	13·98	9·13	11·55	18·0	1·6	Aug.	11·97	6·42	9·19	14·0	1·5
Mar.	13·60	9·31	11·45	17·5	1·5	Sept.	11·32	6·78	9·05	17·3	1·9
April	12·28	8·05	10·16	16·2	1·6	Oct.	13·33	7·87	10·60	19·0	1·8
May	11·86	7·83	9·84	14·7	1·5	Nov.	14·43	8·63	11·53	18·6	1·6
June	11·07	6·91	8·99	15·8	1·8	Dec.	13·80	8·63	11·21	17·9	1·6

The ratios of the velocities of storm centers to the mean velocities of the wind, are quite different from those found for the United States, and the correspondence between the rate of storm movements and the movement of the wind is not as distinctly marked. Nevertheless some degree of correspondence can be detected, and it is noticeable that in Europe the change in the wind's mean velocity for the different months of the year is only about half as great as in the United States. The inequalities in the value of the ratio for the different months are considerable, and indicate the operation of some other cause than the mean velocity of the wind.

I next determined the average velocity of the wind in the neighborhood of the Bay of Bengal and China Sea. The following table shows the results which I have obtained, the observations being mostly derived from the Report on the Meteorology of India for 1882. I have employed only stations south of lat. 20° and I have rejected all stations having an elevation greater than 3000 feet.

	Coast Sta.	Inland Sta.	Mean.	Storms.	Ratio.		Coast Sta.	Inland Sta.	Mean.	Storms.	Ratio.
Jan.	6·00	3·79	4·89	----	---	July	9·12	7·67	8·38	8·36	1·0
Feb.	5·46	4·13	4·79	----	---	Aug.	8·29	6·58	7·43	10 30	1·4
Mar.	5·33	4·54	4·93	----	---	Sept.	7·46	5·50	6·48	9·77	1·5
April	5·71	5·00	5·35	7·54	1·4	Oct.	5·79	3·46	4·63	9·26	2·0
May	7·17	6·21	6·69	8·54	1·3	Nov.	5·25	3·50	4·37	7·38	1·7
June	9·12	7·83	8·47	5·62	0·7	Dec.	5·71	3·75	4·73	----	---

The number of coast stations is 17, and the number of inland stations is also 17. The velocities are all expressed in miles per hour. The ratios of the velocities of storm centers to the mean velocities of the wind differ sensibly from those found for Europe, and differ very greatly from those found in

the United States. Moreover we find no correspondence between the average rate of progress of storm centers for the different months of the year, and the average velocity of the wind. The inequality in the values of the ratio for the different months of the year is quite noticeable, but this may be partly due to the small number of the observations.

I next endeavored to determine the mean velocity of the wind in the neighborhood of the West India Islands, but found observations for only seven stations south of lat. 27°. The following table shows the results for August, September and October, which are the only months for which there is an observation of more than one cyclone, with the exception of June, for which month there are three observations.

	Velocity.		Ratio.
	Wind.	Storms.	
August	5·79	14·44	2·5
September	5·98	14·00	2·3
October	6·70	12·81	1·9

I next determined the mean velocity of the wind for that part of the Atlantic Ocean in the neighborhood of the usual tracks of storm centers, and have adopted the results contained in No. 3 of the Mittheilungen aus der Norddeutsche Seewarte. The first line of the following table presents a summary of these results for the four seasons of the year, the force of the wind being estimated in units of Beaufort's scale (1–12).

	Winter.	Spring.	Summer.	Autumn.
Beaufort's numbers	5·9	5·5	4·5	5·3
Miles per hour	33·0	30·8	25·5	29·7
Storms	18·4	18·6	16·5	18·6
Ratio	0·5	0·6	0·6	0·6

The second line shows the velocities denoted by Beaufort's numbers, reduced to miles per hour according to the table prepared by the British Meteorological committee; the third line shows the average rate of progress of storms, and the fourth line shows the ratio of the numbers in the two preceding lines.

If we group together the results now obtained, we shall have the following summary for the average rate of progress of storm centers, the average velocity of the winds, and the ratio of these two velocities:

	Storms.	Winds.	Ratio.
United States	28·4	9·5	3·0
North Atlantic Ocean	18·0	29·8	0 6
Europe	16·7	10·3	1·6
West Indies	13·7	6·2	2·2
Southern Asia	8·4	6·5	1·3

This table appears at first view to present a discouraging medley of anomalies, but some of the anomalies may appear less formidable after a careful examination. It seems highly probable that the slow progress of storm areas in southern Asia is partly due to the small velocity of the winds of that region. It is not obvious why storms should travel more rapidly near the West India Islands than in the China Sea. It is possible that this anomaly may disappear when the mean velocity of the wind has been determined by a more extended series of observations.

It seems to be established that over the Atlantic Ocean the mean velocity of the wind is considerably greater than the rate of progress of storms. This inequality is strikingly exhibited in numerous cases. Over this Ocean, we frequently find an area of low pressure, 2000 miles or more in diameter, with a pressure of about 28 inches at the center, attended by winds blowing with hurricane violence, while from day to day the center of the low area makes little or no progress eastward, showing that the movement of the atmosphere which corresponds to the average system of circulation, is almost entirely interrupted over this ocean.

The most noticeable anomaly shown in the preceding table is however presented by the United States, where the mean velocity of the wind is only one-third as great as over the Atlantic Ocean, but storms travel with nearly double velocity. This anomaly may be partly explained if we admit that the progress of storms is determined, not by the wind which prevails in close contact with the earth's surface, but by that which prevails at an elevation of several hundred feet, where the velocity is probably much greater than at the earth's surface. The same anomaly however is found when we compare the storms of the United States with those of Europe. In northern Europe the surface winds have a velocity greater than those of the United States, and we may infer that the same is true for elevations of 1000 or 2000 feet above the surface; yet storms in Europe advance with but little more than half the velocity of those in the United States. There must then be a powerful cause which accelerates the movement of storm areas in the United States, and which does not operate in Europe or over the Atlantic Ocean; and apparently the same cause does not operate in southern Asia, or in the West Indies, at least in an equal degree. This cause (or one of these causes) is probably the precipitation in the form of rain or snow which, in the United States, usually takes place on the east side of a storm area, greatly in excess of that on the west side, as I have shown in my seventeenth paper; but for the interior of Europe the same does not appear to be true, or certainly not in an equal degree, as I have shown in my twelfth paper.

ART. II.—*Note on some Paleozoic Pteropods;* by CHARLES D. WALCOTT, *of the U. S. Geological Survey.*

IT is with considerable reservation that I place the genera Conularia, Hyolithes, Hyolithellus, Coleoprion, Coleolus, Hemiceras, Salterella, Pterotheca, Phragmotheca, Matthevia and perhaps Palænigma under the Pteropoda. They form a group that, although representative, in a measure, of the recent Pteropoda, differ in other respects so much that it appears as though a division of the Gasteropoda, equivalent to the Pteropoda, might be consistently made to receive them.

I have had in my possession for two years past the specimens on which the genera Matthevia is founded, and it is of such interest that I take the opportunity of publishing it before bringing out the illustrations of the fauna with which it is associated.

Genus MATTHEVIA, n. gen.

Shell conical, aperture sinuous, transverse section ovate, elliptical or rounded subquadrate; interior with two elongate chambers diverging from the apex and opening into a large, single, terminal chamber; both of the interior chambers are crossed by a single imperforate septum; calcareous; surface papillose. Operculum calcareous, nucleus excentric, lines of growth concentric.

Type *Matthevia variabilis.*

The generic name is proposed in honor of Mr. G. F. Matthew, who is doing so much good work on the St. John fauna.

This peculiar shell is so distinct from all described forms referred to the Pteropoda, that a new family, Matthevidæ, is instituted to receive the one genus now known.

In form and surface markings it approaches the genus Conularia; the operculum may be compared to that of Hyolithes, and the imperforate transverse septum allies it to both Hyolithes and Conularia. Its thick shell is observed in the genera Conularia, *C. fecunda* Barr. (Syst. Sil. Boheme, vol. iii, pl. viii, fig. 8), and Hemiceras, *H. cylindricus* Eichwald (Leth. Ross., vol. i, Atlas, pl. xl, fig. 17; pl. xlii, fig. 29). When we come to trace a relationship to the two inner chambers, we are, at once, at a loss for comparisons.

There is a curious form described as *Tetradium* Wrangeli* Schmidt (Mem. Acad. Imp. Sci. St. Petersbourgh, VII. Ser.,

* The genus Tetradium being preoccupied (Dana, 1846; Safford, 1856), I propose Palænigma in place of Schmidt's Tetradium, 1874, for the species under consideration—*P. Wrangeli.*

vol. xxi, No. 11, p. 42, figs. 3–8, 1874), which Lindström suggests is, by the thick-shelled *Conularia fecunda* Barrande, linked to Conulariæ and made to stand in affinity to them. (Sil. Gasteropoda and Pteropoda of Gotland, p. 41, 1884.) From our comparisons Matthevia appears still more to serve as a connecting link between Palænigma and the genera Conularia and Hyolithes. If *P. Wrangeli* had chambers running up into the shell, as is suggested by the cross-sections, and a septum that caused the upper portion of the shell to be decollated, as we are led to believe by the natural section, and the fact that each specimen figured has lost its apex, the relations between Palænigma and Matthevia are quite close and Palænigma may be provisionally grouped with the genera Matthevia and Conularia.

MATTHEVIA VARIABILIS, n. sp.

On a side view, the outline of the shell varies from broad to narrow conical, and the end view shows an elongate conical to a broad conical outline; the cross-section varies from elliptical to oval or rounded quadrangular; aperture varies in outline with the proportions of the shell; a sinus, varying in depth and curvature, extends across the ends of the shell; in the more elliptical apertures the sides are nearly straight and parallel, while, in those with a subquadrangular outline, they are strongly curved, and the sinus at the ends is very profound. The shell thins out at the edges and is not thick over the exterior of the interior chambers, but between them a connecting mass of shell unites the sides and gives strength and solidity; a section, crossing the center of the shell at right angles to the preceding, shows a solid shell to the outer chamber where it gradually thins out to the margin. The position of the two inner chambers vary in relation to each other, from subparallel to widely divergent; the chamber that is more at right angles to the aperture than the other, is usually larger, and is always prominent, while the oblique chamber is sometimes filled up by shelly matter and only the outer portion remains; both chambers are usually flattened on the inner side, and more or less expanded where they enter the large outer chamber. The septum crossing the inner chamber is thin, and varies in shape with the form of the chambers; it is usually slightly concavo-convex, concave towards the outer chamber, and marked, usually, by a raised scar of varying character; the septum is usually a short distance from the outer chamber—1^{mm} to 4^{mm}.

The substance of the shell is calcareous.

Surface marked by undulating lines of growth parallel to the margin of the aperture, a few radiating lines usually on the

sides, and fine papillæ, arranged in lines that cross each other at right angles, on some shells; on others, the papillæ are arranged in lines parallel to the lines of growth and without reference to the order of those in the adjoining lines; the interior surface is covered with a fretted work brought out by depressed, irregular, inosculating lines; this surface varies in force and character, and some shells are almost smooth inside; a narrow, smooth space extends all around the margin of the inside of the aperture.

The associated operculæ vary in form and outline; the shell is calcareous, concavo-convex, rising to a blunt point more towards one end than the other; from this point long, narrow, radiating undulations extend to the margin, and it is the center of the concentric undulations of growth. Surface with concentric and radiating undulations, fine, inosculating lines, subparallel to the concentric undulations, and fine papillæ on the spaces between the inosculating lines; interior surface convex, smooth or showing the undulations of the outer surface; at the center, corresponding to the apex of the outer surface, a small, round scar appears to be indicated on some specimens.

The only form known to me that corresponds in any way to this, is that figured by Eichwald (Leth. Ross., pl. xl, fig. 19, *a*, *b*, *c*), as *Hyolithes paradoxus*, which appears to be the cast of a portion of the outer chamber and one of the conical inner chambers; it may be only a superficial resemblance.

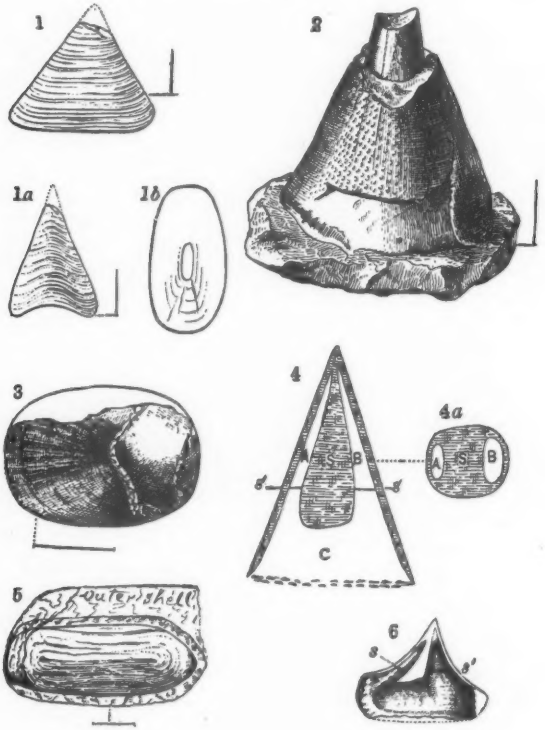
Formation and locality.—Cambrian. Limestone resting on Potsdam sandstone, one mile northwest of Saratoga Springs, N. Y.

The species is associated with *Cryptozoan proliferum* Hall (Thirty-sixth Ann. Rep. N. Y. State Mus. Nat. Hist., despt. of pl. vi, 1884), *Platyceras minutissima* W., *Ptychoparia* (L.) *calcifera* W., *Dicellocephalus Hartti* W., and *Ptychaspis speciosus* W. (Thirty-second Ann. Rep. N. Y. State Mus. Nat. Hist.)

Note on Hyolithes (*Camarotheca*) *Emmonsi* Ford.—When studying the species of Hyolithes from the Georgian Group, I found that the shell of *H. Emmonsi*, of Ford, was formed of three or more distinct layers: first, a thin outer layer with rather strong even striæ that cross the flattened ventral face nearly direct, and arch forward on the dorsal face, the flattened side, in this species, being the ventral face and not the dorsal, as in most species; the second layer appears to be of a smooth, even character, much like a filling between the outer and inner shell; the inner shell is thin and concentrically striated in a slightly different manner from the outer shell; a fourth layer appears to exist in one example, but it is too obscure for study.

Another character observed is one that, as far as I know, has

not yet been noticed in any American species of the genus, although observed in some species of the genera Conularia and Matthevia. It is the presence of a transverse diaphragm in the tube towards the apex. This appears to have caused the shell



MATTHEVIA. DESCRIPTION OF FIGURES.

1, Side view of a small but characteristic form of the shell. 1*a*, End view of same. 1*b*, Outline, from the apex.

2, End view of one of the more circular shells enlarged to show the surface. The shell is broken away near the summit, and shows the cast of one of the inner chambers.

3, Operculum associated, in the same hand specimen of rock, with *M. variabilis*.

4, Longitudinal section of conical shell. *A*, *B*, inner chambers. *C*, chamber of habitation. *S*, thick shell between the inner chambers. *s'*, *s'*, position of the septa separating the chamber of habitation and the inner chambers. 4*a*, cross-section taken a little above the septa.

5, Enlargement of the surface of a septum.

6, Cast of the chamber of habitation and the inner chamber within the septa (*s*, *s'*) of the most common form of the shell.

to become deciduous in many instances, and we now find numerous examples showing the blunt terminal portion. Some shells show the rounded, smooth end without any constriction; others have a narrow concentric constriction just within the termination. The cast of the surface of the septum shows a slight central cicatrix or scar, but no evidence of a perforation in the septum could be observed. The average size of the tube, at the point of decollation, is 1^{mm}. The largest seen is 1·5^{mm} and the smallest ·75^{mm}.

When studying the septum, the close similarity between it and that of the first septum of the species of Orthoceras and Cytoceras, as figured by Barrande (Cephalopodes, Etudes generales, 1877, pls. 487, 488), were, at once, brought to mind, and also the interesting question of the relations of these shells to the cephalopoda.

Since the above was written I have received a paper from Mr. G. F. Matthew, in which he states that several of the Pteropod shells, from the base of the St. John group, have several distinct septa at the base of the tube. The genus and species is not mentioned (Nat. Hist. Soc. N. B. Bull., 10, p. 102, 1885).

Mr. Matthew quotes, in the same paper, from a letter written by Mr. Alpheus Hyatt, where the latter says: "These fossils with their distinct septa are startlingly similar to certain forms of Nautiloidea, but there is no siphon. They, however, confirm Von Jhernig's and my opinion that Orthoceratites and Pteropods have had a common, but as yet undiscovered, ancestor in ancient times."

In a letter dated April 9, 1885, Mr. Matthew states that he has several species of the Hyolithellidæ from the St. John Group that have several septa toward the apex of the tube for which he has proposed two generic divisions, one of which he calls Camarotheca; this will probably include *H. Emmonsi*, and I have used the name in a subgeneric sense, until I can learn more of the character of the septa of *H. Emmonsi*.

A single specimen of *H. primordialis*, from the Potsdam sandstone of Wisconsin, also shows evidence of a transverse septum.

NOTE OF CORRECTION.—In describing the figures accompanying the article on Linnarssonia (this Journal, vol. xxix, February, 1885, p. 117), figs. 1 and 2 are given as those of *Obolella chromatica*, and credited to Mr. Billings. The artist, in preparing the figures, copied, by mistake, those of *Obolella crassa* Ford. The fact escaped my notice at the time, and I unintentionally credited Mr. Billings with figures that had been published by Mr. S. W. Ford. C. D. W.

ART. III.—*A Determination of the B. A. Unit in Terms of the Mechanical Equivalent of Heat;* by LAWRENCE B. FLETCHER, Ph.D.

THE experimental work of the following investigation was completed in 1881, and forms the subject of a thesis submitted to the Johns Hopkins University in that year. In the present paper a more accurate method of calculating the currents from the deflection-curves is used, and some of the other calculations have been revised. The results of the two papers are substantially the same.

The experiment consisted of simultaneous thermal and electrical measurement of the energy expended by a current in a coil of wire immersed in a calorimeter. The result depends upon the values of the mechanical equivalent and the unit of resistance, and gives a determination of either in terms of an assumed value of the other.

The old determinations of Quintus Icilius and Lenz have no value, as the resistance is uncertain as pointed out by Rowland and H. F. Weber.

Joule,* in 1867, made a determination of the mechanical equivalent by this method, assuming the B. A. unit as determined by the committee in 1863–4 to be equal to 10^9 C. G. S. units. The value of the mechanical equivalent thus obtained is more than one per cent greater than Joule's water-friction value. H. F. Weber,† in 1878, used a similar method, employing the Siemens unit, the value of which he also measured in C. G. S. units. Weber's value of the mechanical equivalent is about one part in two hundred greater than Joule's water-friction value and one part in four hundred greater than Rowland's water-friction value.

In both Joule's and Weber's experiments a possible source of error seems to have been ignored. The wire was assumed to be at the temperature of the water in which it was immersed, and its resistance was calculated on this assumption. It is evident, however, that the wire was hotter than the water, inasmuch as it was giving heat to the water. The error due to this cause is of uncertain amount. If corrected for this error the value of the equivalent would be increased and their excess over the water-friction values would become greater than before. To avoid this source of error, the research described below was planned. The suggestion and general plan of the research I owe to Professor Rowland.

The theory of the method is as follows: A current c, flow-

* Report of B. A. committee on electrical standards, 1873.

† Phil. Mag., Series 5, vol. XXX.

ing through a wire of resistance R, for a time t, generates an amount of heat represented by $h=\frac{c^2Rt}{J}$ where J is the mechanical equivalent of heat. The wire being immersed in a calorimeter and put in a circuit with a galvanometer, h, c and t can be measured. Then if R is measured in B. A. units the experiment will give a relation between the value of that unit and the mechanical equivalent. In this research R was measured during the actual experiment by connecting its terminals with those of a large resistance R′ and measuring the current c', which flowed through the latter. With this arrangement $cR=c'R'$, or $R=\frac{c'}{c}R'$. Hence $J=\frac{cc'R't'}{h}$, in which R does not appear, and the uncertainty attaching to its temperature has no effect.

The calorimeter was a cylindrical cup of sheet copper holding about 800^{cc}. On the bottom of the cup lay a sheet copper frame which supported three vertical glass rods. Around these the wire, R, was coiled, forming a helix. The ends of the wire were soldered to stout copper wires which, insulated by short vulcanite tubes, passed through the wall of the calorimeter and turned down so that they could be placed in mercury cups. The cover of the calorimeter rested in contact with the water to secure uniformity of temperature. The cover had an expansion tube and a smaller central tube which formed one bearing for the stirring apparatus, another bearing being given by a brass socket on the bottom of the calorimeter. The stirrer consisted of a spiral blade of sheet copper supported on a brass frame, the upper part of which was tubular, and passed through the central tube of the cover. The stirrer was kept in motion during the experiment by a silk thread, which passed over a vulcanite wheel at the top of the stirrer and ran to a driving clock. The stirrer formed the escapement of the clock, which ran very uniformly with this arrangement. I estimated the heat generated by the stirrer as two-thirds of the whole work of the weights. This is about one thousandth part of the heat generated by the current and only a rough determination of the correction is needed. The thermometer passed through the tubular upper part of the stirrer, and was clamped to a shelf above in such a manner that its bulb was in the centre of the calorimeter and surrounded by the stirring blade which, in turn, was surrounded by the wire which carried the current. The wire was composed of an alloy of platinum and iridium, and was varnished to prevent conduction to the water. Its resistance was about 1·8 ohm. The calorimeter was supported on legs of vulcanite within a copper vessel with double walls, the space between which was filled with water. This water-

jacket was provided with a hollow cover, also filled with water, and its inner surface and the outer surface of the calorimeter were nickel-plated and polished. Thus the calorimeter was nearly surrounded by an envelope of fairly constant temperature, the thermometer, stirrer-thread and connecting wires passing through openings in the jacket.

From the mercury cups in which the electrodes of the calorimeter dipped, the wires of the main circuit ran to the battery and galvanometer. These wires were $2{\cdot}5^{mm}$ in diameter, cotton-covered, carefully paraffined and twisted together to eliminate direct action on the needle. The battery consisted usually of 24 one-gallon bichromate cells arranged 4 in series and 6 abreast, and gave a very steady current. In one experiment only 20 cells were used, 4 in series and 5 abreast. The galvanometer coil for the main current was a single turn of stout wire laid in a groove on a wooden circle of about 80^{cm} diameter. A sine galvanometer was so placed that its needle was in the axis of the single wire coil and about $\cdot1^{cm}$ distant from its plane. This excentricity was rendered necessary by the length of the suspending fibre. The coil of the sine galvanometer was connected with the calorimeter electrodes by a second circuit, in which a resistance coil of 30,000 ohms was included. The wires of this circuit were kept apart, as the current was too small to exert an appreciable direct action, and as great irregularity in some preliminary experiments in which the wires were twisted together was finally traced to leakage, although the wires had a double covering of silk. Both circuits were provided with commutators. The sine galvanometer had a horizontal bar parallel to the axis of the coil. To one end of this was attached a telescope, beneath which was a short scale which was seen by reflection in the mirror of the needle, and allowed a very accurate setting to be made without bringing the needle to rest. The needle consisted of two thin strips of steel $1{\cdot}2^{cm}$ in length separated by a piece of wood $\cdot6^{cm}$ in thickness. The circle of the galvanometer was graduated to half-degrees and read by verniers to one minute.

The needle was acted upon by both currents simultaneouly, and by means of the commutators the actions were caused to be in the same and in opposite directions alternately. The current through the sine galvanometer is c' in the formula $J=\frac{cc'R't.}{h}$ The current through the coil on the wooden circle is $c+c'$, and was assumed equal to c as c' was less than $\cdot00007c$. Let G denote the constant of the fixed coil, G′ that of the sine galvanometer, H the horizontal magnetic force, θ and θ' the deflections when the actions are in the same and in opposite directions respectively. Then

$$Gc\cos\theta + G'c' = H\sin\theta$$
$$Gc\cos\theta' - G'c = H\sin\theta'$$

Hence $c=\frac{H}{G}\tan\frac{1}{2}(\theta+\theta')$, $c'=\frac{H}{G}\frac{\sin\frac{1}{2}(\theta-\theta)}{\cos\frac{1}{2}(\theta+\theta')}$

Let l denote the length of the wire in the fixed coil and b the distance of the needle from its plane. Then $G=\frac{4\pi^2}{l(1+\frac{6\pi b^2}{l^2})}$

Hence the equation for J becomes

$$J=\frac{\left(R'l(1+\frac{6\pi^2b^2}{l^2}\right)}{4\pi^2G'}\ \frac{H^2l}{h}\ \frac{\tan\frac{1}{2}(\theta+\theta')\sin\frac{1}{2}(\theta-\theta')}{\cos\frac{1}{2}(\theta+\theta')}$$

I shall discuss in order the quantities contained in this expression.

R′, the resistance of the secondary circuit, is the sum of the resistances of the 30,000 ohm coil, the sine galvanometer and connecting wires. The whole was measured by connecting the terminals of the circuit with a Jenkin bridge and comparing with other coils, using a high resistance Thomson galvanometer. The provisional standard was a 10 ohm coil, A, made by Warden, Muirhead and Clarke. From this coil the resistance of a 100 ohm standard, B, was obtained by means of a comparator, C, of 10 coils, each nearly equal to A, each coil of C being compared with A, and C in series then compared with B. Then A, B and C were arranged to form a bridge with D, a 1,000 ohm standard, whose resistance was thus fixed. E and F, two 1,000 ohm coils of a resistance box, were then compared with D. Finally a bridge was formed with A, B, D+E+F, and R′, the secondary circuit, giving R′ in terms of A. Elliott's coils were used in making the adjustments, which were always very small, and the temperatures were carefully observed. The result is

$$R'=30012{\cdot}4 \text{ at } 19°{\cdot}3 \text{ C.}$$

R′ consisted principally of the 30,000 ohm coil and the variation of this only need to be considered. Its temperature varied from 19° to 24° when in use, the mean temperature being 22°·3 C. At this temperature, R′=30052, which value was used throughout.

The length of the wire in the fixed coil was determined by measuring with a steel tape the distance between two threads fastened on the wire before it was placed on the circle. When the wire was in position, the interval of a few centimeters between the threads was measured. The tape had been compared with standards. Care was taken to avoid difference of tension in the two positions of the wire. The result is $l=264{\cdot}49^{cm}$.

The quantity b, the excentricity of the needle, was estimated by holding the tape horizontally over the top of the circle and reading the positions of the center of the wire and the galvanometer fiber. For most experiments $b=1{\cdot}2^{cm}$. It was frequently re-measured and a correction applied when it varied. The method of measurement is not very accurate, but an error of 10 per cent in b, which could hardly occur, would only involve an error of 1 part in 3,000 in J.

G′ had been determined by Professor Rowland* by measurement during the construction of the coil, and also by comparison with another coil. The values are 1832·24 by measurement and 1833·67 by comparison. The mean, giving the second value twice the weight of the first, is 1833·19.

Hence the constant term $= 10996+10^7$.

G′ has recently been re-measured and found to be 1832·53. My final result is corrected to this value.

H was measured in the following manner: The circle bearing the fixed coil carried four smaller wires which could be connected with the battery and an electrodynamometer of the form described in Maxwell's treatise. These four wires with the needle formed a tangent galvanometer, the other coils being open. Eight pairs of simultaneous readings of the galvanometer and electro-dynamometer were taken comprising all possible combinations of signs of the currents in the galvanometer and the two electro-dynamometer coils. I am greatly indebted to Professor S. H. Freeman, then Fellow of the University, for assistance in these readings.

The expression for H is

$$H=\frac{4\pi^2 nC\sqrt{I}\left(1-6\frac{\pi^2 b'^2}{l'^2}\right)}{l'}\ \frac{\sqrt{\sin\alpha}}{T\tan\varphi}$$

where C is a function of the dimensions of the electrodynamometer coils, I the moment of inertia of the suspended coil, n the number of turns of wire in the galvanometer, l' the mean length of one turn, b' the mean distance of their planes from the needle, T the time of vibration of the small coil, α and φ the mean deflections of electrodynamometer and galvanometer.

C was known from measurements during the construction of the instrument, and I had been determined by observing times of vibration with and without the addition to the suspended coil of bars of known moment of inertia. These values of C and I had been verified by Dr. E. H. Hall and myself in connection with a previous research by comparing the values of H obtained by this method and by the magnetic method, the arrangement of the experiment being such as to make the

* This Journal, xv, 337, 1878.

two results obtain for the same point and time. The value of $C\sqrt{I}$ is 0·18567.

The measurements of l' and b' were made in the same manner as those of l and b.

The results are $l' = 263{\cdot}91\ cm$, $b' = 2{\cdot}07\ cm$, for most experiments. A correction was applied when b' varied. Hence

$$\frac{4\pi^2 n\, C\sqrt{I}}{l'}\left(1-6\frac{\pi^2 b'^2}{l'^2}\right) = {\cdot}11069.$$

Each of the angles, α and φ, is the mean of eight readings taken to 1′. The former was about 13°, the latter 6°. T was obtained by observing ten transits with a seconds clock, allowing the coil to vibrate for several minutes and then taking ten more transits. The difference between the mean times of the two series divided by the number of vibrations gives T very exactly. The difference between the values before and after the experiment never exceeded 1 part in 3000. The mean value is about 2·42 seconds. H was determined before and after the main experiment.

The quantities in the formula for J remaining to be discussed are t, h and the deflections. To treat these intelligibly I proceed to describe the method of experiment exactly.

First, a determination of H was made. The calorimeter was then weighed, filled with distilled water at a temperature usually 2° or 3° below that of the air, carefully wiped with a towel to remove moisture, again weighed and placed in the water-jacket. Its amalgamated electrodes were placed in the mercury cups with the terminals of the two circuits, the main circuit being broken at the commutator. The water-jacket was kept permanently filled and stood in a room of fairly constant temperature so that its temperature changed little during the experiment. The thermometer was placed in position and the stirrer started. During a few minutes readings were taken of the thermometer and of three auxiliary thermometers, giving the temperatures of the jacket, the 30,000 ohm coil and the air near the stem of the principal thermometer, the time of each reading being noted by a seconds clock. The circuit was then closed and a galvanometer reading taken, one of the commutators was reversed and another reading taken, the time of each reading being noted. The time of passage of the mercury of the thermometer over several successive scale-divisions was then taken, also readings of the other thermometers. Two more commutator reversals and galvanometer readings followed, then another set of thermometer readings, and this alternation was continued for about 40 minutes, during which time the thermometer rose about 12° C. Usually sixteen galvanometer readings were taken and seven groups of thermometer readings comprising 35 or 40 readings of the principal thermome-

ter. Then the circuit was broken and the calorimeter allowed to cool for two or three hours, during which time groups of readings were taken as before, the stirrer being kept in motion. While this radiation experiment was in progress another determination of H was made. Finally the thermometer was removed and the calorimeter taken out and weighed.

The mean of each group of thermometer readings, corrected for stem error, gives very exactly the temperature of the thermometer for the mean time of that group. The difference between any two of these mean temperatures, corrected for radiation, gives by multiplication into the capacity of the calorimeter and contents the heat generated in the interval. Hence any two groups give a determination of J when combined with the proper values of θ and θ'.

I have combined groups taken 18 to 25 minutes apart, the rise of temperature being 6° to 8°.

In this calculation the differences of temperature of coil, water and thermometer are assumed to be constant for this interval. The water is cooler than the coil and the thermometer cooler than the water. Both differences depend upon the rate of generation of heat, and may be put approximately proportional to the square of the current. The rise of the thermometer after breaking the circuit is due to these differences and was found to be less than 0°·05. The variation of this quantity during the interval in question would be about 3 per cent, as the current changed 1·5 per cent. Hence the variation is 0°·0015, and as the rise of the thermometer is 6° or 8°, the error is negligible.

Two thermometers were used, designated as Baudin 6165, and Baudin 7320. The former is graduated in millimeters, of which about 12 equal 1° C. It had been used by Professor Rowland in his determination of the mechanical equivalent and compared several times with the air thermometer. Baudin 7320 is graduated to 0°·1 C. one degree occupying about a centimeter. It had been compared with standard thermometers, its errors plotted and the error for each degree obtained from the curve. The following tables give the reduction to the absolute scale.

The table for 6165 is condensed from Professor Rowland's paper* on the mechanical equivalent. Change in the zero point has no effect on the differences of temperature used, but the zero points were determined occasionally in order to get the mean absolute temperature.

The correction for radiation was made in the following manner: The groups of thermometer readings taken after breaking the circuit were reduced to mean readings at mean times. Any two of these mean readings gave the radiation for the

* Proceedings of the American Academy of Arts and Sciences, 1880.

intervening time. If t' and t'' are the temperatures at the beginning and end of an interval of T minutes, and τ is the

BAUDIN 6165.

Reading in mm.	Temperature on absolute scale from 0° C.	Reading in mm.	Temperature on absolute scale from 0° C.
35	0°·0	320	24°·547
50	1°·368	330	25°·365
100	5°·839	340	26°·174
150	10°·183	350	26°·981
200	14°·450	360	27°·782
250	18°·709	370	28°·584
260	19°·557	380	29°·376
270	20°·401	390	30°·170
280	21°·242	400	30°·965
290	22°·076	410	31°·786
300	22°·907	420	32°·581
310	23°·731		

BAUDIN 7320.

Reading.	Temperature on absolute scale from 0° C.	Reading.	Temperature on absolute scale from 0° C.
0°	0°·122	23°	23°·108
5°	5°·092	24°	24°·122
10°	10°·110	25°	25°·137
15°	15°·090	26°	26°·152
16°	16°·093	27°	27°·166
17°	17°·094	28°	28°·179
18°	18°·091	29°	29°·192
19°	19°·086	30°	30°·205
20°	20°·081	31°	31°·217
21°	21°·085	32°	32°·230
22°	22°·095		

mean temperature of the jacket during the interval, then $t'-t''=c\mathrm{T}[\frac{1}{2}(t'+t'')-\tau]$, where c is the coefficient of radiation. In the calculation of c, stem-corrections were applied and a correction made for the heat generated by the stirrer. Hence in the main experiment the temperature correction for an interval T′ is $\Delta=c\mathrm{T}'[\frac{1}{2}(s'+s'')-\tau']+\mathrm{K}$, where s' and s'' are the observed temperatures corrected for stem-error, τ' is the mean temperature of the jacket and K is the stirrer-correction. The sum of the corrections Δ from the beginning of the experiment added to the stem-corrected observed temperature at any point gives the temperature which would have been reached in the absence of radiation. The difference between any two of these theoretical temperatures multiplied by the heat capacity, gives the heat generated in the interval.

The coefficients of radiation were found to decrease with decreasing difference of temperature between calorimeter and jacket. When this decrease was regular the corresponding value of c was used for each small interval of the main experiment. When the decrease was small and irregular, the mean value of c for that day was used throughout. In the revision of the calculations, stem and stirrer corrections were neglected in the calculation of both c and Δ, it being obvious that, both being small and quite regular, they are eliminated in this way, and the value of c corresponding to the difference between calorimeter and jacket for each small interval of the main experiment was used in all cases. The mean results of the two methods differ about 1 part in 1,000, and the figures in the table of results below are the means of both calculations

The mean values of c for the different experiments vary between 0°·0035 and 0°·0046, the general mean being 0°·0040.

The mean radiation correction is about 5 per cent, and is the most important source of variable error in the experiment, as the temperature differences are small and errors of reading have a large effect. But a ten per cent error in the radiation would only involve an error of 1 part in 200 in J, and as the errors are irregular they are in a great measure eliminated from the final result.

The calorimeter was composed of 246 gr. copper, 45 gr. brass, and 6 gr. solder. The specific heat of a mixture of these proportions was measured with Regnault's apparatus. Six determinations gave the value ·0899±·0005 for the mean specific heat between 24° and 100°. Reduced by Bède's law for copper to the mean temperature of my experiments, it becomes ·0877. The capacities of the coil and glass rods were calculated from published tables. The whole capacity is as follows:

Calorimeter	302·1×·0877=26·49
Coil	32·5×·0324= 1·05
Glass rods	9·0× ·177= 1·59
Thermometer estimated at	1·25
Total capacity	30·4

The values of the deflections were obtained by a graphical method. The galvanometer readings fell into 4 groups, lying about 26° and 3° 45′ on each side of the zero point. The readings of each group were plotted separately as functions of the time. From each curve the theoretical mean readings for each interval between two temperatures used in the calculation of J were obtained by measuring a large number of equidistant ordinates, calculating the area of the curve and dividing by the base line. If a, b, c and d are the mean readings thus obtained, $2\theta=a-b$ and $2\theta'=c-d$ as the galvanometer was graduated from 0° to 360°. Thus the zero point was not used, though observed before and after each experiment.

Below are the results of one experiment in detail. Each value of J is calculated from the two temperatures found in the same horizontal line.

Series of December 9th.

	gr.
Weight of calorimeter and water before experiment	1157·2
Weight of calorimeter and water after experiment	1157·0
	1157.1
Weight of calorimeter	343·7
	813.4
Capacity of calorimeter	30·4
	843·8
Capacity reduced to weight in vacuo	844·8

Horizontal magnetic force before experiment..... ·1960
Horizontal magnetic force after experiment..... ·1963

Mean ..... ·19615

Temperature of jacket ..... 21°·5 to 21°·6
Temperature of air near stem..... 22°·8 to 23°·4
Temperature of 30,000 ohm coil..... 21°·5 to 22°·3
Thermometer in calorimeter..... Baudin 7320

Time.	Reading 7320.	Stem.	ΣΔ.	Time.	Reading 7320.	Stem.	ΣΔ.	$2\theta°$.	$2\theta'$.	J.
m. s.				m. s.						
8 40	19°·45	−·010	0	25 14	25°·40	+·009	+·056	51° 8′·4	7° 35′·6	41810000
13 16	21°·15	−·007	−·018	31 9	27°·40	·021	·167	50° 57′·5	7° 28′·5	41640000
20 38	23°·80	·000	+·005	35 58	28°·98	·029	·299	50° 48′·5	7° 24′·4	41640000
25 14	25°·40	+.009	·056	42 54	31°·15	·039	·565	50° 40′·4	7° 21′·4	41840000

Time.	Galvanometer.	Time.	Galvanometer.	Time.	Galvanometer.	Time.	Galvanometer.
m. s.		m. s.		m. s.		m. s.	
7 50	237° 14′	15 40	237° 11′	28 5	237° 5′	39 0	237° 2′
7 0	259° 12′	17 5	258° 56′	29 15	258° 46′	41 0	258° 40′
10 20	229° 34′	22 0	229° 40′	32 45	229° 42′	44 15	229° 44′
11 30	207° 42′	23 25	207° 58′	34 0	208° 0′	45 25	208° 4′

Following is the general table of results:

Date.	Nov. 24.	Dec. 9.	Dec. 14.	Dec. 20.	Dec. 22.	Jan. 26.	Feb. 16.
Thermometer ..	7320	7320	6165	6165	6165	6165	6165
Temp. of water	24°·3	25°·4	27°·0	26°·6	26°·3	27°·2	26°·2
Temp. of R′ ...	23°·0	22°·1	23°·8	21°·7	23°·4	19°·1	20°·6
$\frac{J}{10000}$	4240 4248 4229 4274 4216 4217 4204 4225 4225 4224	4181 4164 4164 4184	4180 4222 4217	4207 4195 4206 4204 4182	4198 4216 4232 4218	4194 4192 4205 4193	4207 4219 4174
Means	4230	4173	4206	4199	4216	4196	4200

The greater number of results on Nov. 24 is due to the fact that single thermometer readings were taken instead of groups. The two experiments with 7320 show the greatest variation from the mean, but the mean of these two agrees

closely with the general mean. Experiments made on Nov. 29 and Dec. 6 were rejected on account of leakage of 3 and 6 grams respectively. The results, however, are 4220 and 4227, falling within the limits of the series. The duration of the experiment was less than one-fifth of the interval between the two weighings of the calorimeter, and probably the loss during the experiment was the same fraction of the whole loss. Furthermore, the leakage during the radiation experiment would affect the radiation coefficient in such a manner as to approximately compensate for the effect of leakage during the main experiment. For these reasons I have retained the experiments of Jan. 26 and Feb. 16, which showed a leakage of 1 gr. and 1·5 gr. respectively, but have given the results half the weight of the others. The remaining experiments are satisfactory in this respect, the loss being a few tenths of a gram, due principally to the removal of the thermometer.

The result of the experiment is J=42,039,000 O, where O is the value of one-tenth of the 10 ohm coil in earth-quadrants per second. Reduced to the new value for the constant of the sine galvanometer, it becomes J = 42,055,000 O.

I have also calculated the experiment from the formula $J=\frac{c^2Rt}{h}$, where R is the resistance of the calorimeter coil as measured in the ordinary manner, corrected to the mean temperature of the water and further corrected for superheating. I estimated the superheating from observations of the main and derived currents when the strength of the former was varied. The expression $\frac{c'R'}{c}$ should give the true resistance of the coil at any instant. When the currents are smaller the superheating is less and the comparison of the value of $\frac{c'R'}{c}$ for a zero current, obtained by graphical extrapolation, with its value for the full current, should give the superheating. The method is not very accurate, as the observations with the smaller currents are uncertain. I find the increase of resistance due to superheating to be about 1 part in 700, corresponding to a difference of temperature of 2° C. When this correction is applied the second method of calculation gives J= 42,156,000 O.

This result depends upon the square of the main current, and as the temperature of the coil changed 6° or 8° during the experiment, its mean resistance is somewhat uncertain. Hence this result has not the weight of the former.

The discovery of this discrepancy has greatly delayed the publication of this paper. It may be due to conduction to the water, which was guarded against by varnishing the wire and using distilled water, but was not proved not to exist.

For, let E be the difference of potential of the ends of the coil, e the E. M. F. of polarization, R and r the resistances of coil and water respectively. Then the current in the coil is $C=\frac{E}{R}$ and the current in the water is $c=\frac{E-e}{r}$.

The energy converted into heat is

$$C^2R+c^2r=\frac{E^2}{R}\left[1+\frac{R}{r}\left(1-2\frac{e}{E}+\frac{e^2}{E^2}\right)\right]$$

In the first method of calculation above the energy is computed as

$$E(C+c)=\frac{E^2}{R}\left[1+\frac{R}{r}\left(1-\frac{e}{E}\right)\right]$$

In the second method it is computed as

$$(C+c)^2R=\frac{E^2}{R}\left[1+\frac{2R}{r}\left(1-\frac{e}{E}\right)\right]+\text{smaller terms.}$$

E was over 6 volts, e is about 1·5 volts. Hence the second result is larger than the first, which agrees with the facts, and the *error* of the first is less than one-fourth of the difference between the two. The discussion shows that the first method of calculation is to be preferred, and I therefore take J = 42,055,000 O as the result.

Since the completion of my experiments, a 10 ohm Elliott standard in the possession of the University has been compared with the Cambridge standards and found correct at 20°·9 C. My standard has been compared with this with the following result:

$$\frac{\text{W. M. \& C.'s coil,}}{\text{Elliott's coil,}} = 1\cdot00168 \text{ in } 1878$$
$$\text{“ “} = 1\cdot00170 \text{ “ } 1882$$
$$\text{“ “} = 1\cdot00173 \text{ “ } 1883$$

In these comparisons the Elliott coil was taken at 16°·3 C., as marked. Also we have

$$\frac{\text{Elliott coil at } 20°\cdot9}{\text{Elliott coil at } 16°\cdot3} = 1\cdot0014$$

Hence $O=\frac{1\cdot0017}{1\cdot0014}=1\cdot0003$ B.A. units and J = 42,068,000 × value of B. A. unit in earth-quadrants per second.

Rowland* has discussed Joule's values and reduced them to the air thermometer and the latitude of Baltimore. The mean of the best results from the friction of water, in 1850 and 1878, thus becomes 426·55 kilogram-meters or 41,805,000 C.G.S. at 14·1° C. This, according to Rowland's results for the tem-

* Proceedings of American Academy of Arts and Sciences, 1880.

perature variation, corresponds to 41,608,000 at 26°, the mean temperature of my experiments. Rowland's value at 26° is 41,720,000. Combining the mean of these, 41,664,000, with my result, I find 1 B. A. unit$=\frac{41,664,000}{42,068,000}=$ ·9904 earth-quadrants per second.

This research cannot compare in weight with the elaborate determinations of the ohm by direct methods, which have been made in England and this country since the conclusion of my experiments, but as few results by this method are at hand, I publish it as a slight contribution to the history of this vexed subject.

Marlborough, N. Y., April 15, 1885.

ART. IV.—*Cause of Irregularities in the Action of Galvanic Batteries;* by HAMMOND VINTON HAYES and JOHN TROWBRIDGE.

IN the May No. of this Journal, 1885, is described an apparatus devised by Prof. John Trowbridge, for photographing the deflections of a galvanometer needle. A spot of light is reflected from the mirror of a galvanometer, and from a fixed mirror, on to a sheet of sensitive paper. When no current passes, the two spots of light coincide; when the mirror is deflected, one spot marks the zero of the scale; the distance between the two spots shows the amount the mirror has been deflected. In this way all variations of current are accurately registered. We have tested a number of batteries in this way, and have found that in some cases the current was comparatively constant, or if any variation occurred, it was of the nature of a gradual and regular fall. Examples of this action are to be seen in figures 1, 2 and 3. In other cases the action was exceedingly irregular; not only were there many marked variations in the strength of the current, but these variations were made up of a multitude of minor fluctuations. Both of these actions can be observed in figures 4 and 5. The variations in some cases are as great as twenty or thirty per cent of the total strength of the current. It seems, therefore, of interest to find to what causes these changes may be assigned, especially as such variations would seriously affect delicate experiments. Moreover, in batteries used for incandescent lighting it is absolutely necessary to obviate this difficulty.

It was observed that batteries without a porous partition were not subject to these fluctuations. Such batteries as the Leclanché exhibit smooth unserrated curves, whereas all bat-

teries employing porous cups show irregularities more or less marked. It will be noticed that the variations may be divided into two classes, one a general undulation, the other a series of rapid fluctuations which make up the undulations. There are, likewise, two separate actions which cause these irregularities: first a diminution in the current strength, caused by the pores of the partition becoming filled with the base, and thus preventing action until it has been dissolved and fresh acid can attack the zinc; second, a diminution of the acid at the positive pole, and a consequent decrease in current. This action is due to electrical endosmose. The undulations are due to the first of these causes; the fluctuations to endosmose. It will be observed that the fluctuations in all cases begin as soon as the current is made, and before it is possible that the partition can have become so impregnated as to cause an interruption to the current. This can be well seen in figures 4 and 5. This shows that the fluctuations and undulations must be due to different causes. In figure 4 the undulation is very marked. This figure is the photograph of the action of a battery using a very dense porous cup. Figure 3 shows the action with a cup, the same size as that used in figure 4, made of ordinary unglazed paper. We find here no action whatever. We should suppose from the above experiments that the more dense the partition the more liable would it be to become clogged, whereas with a very porous cell there should be very little resistance offered. To prove this, a cup of very porous earthenware was compared with one much denser; figures 7 and 8 show the results. In the case of the porous cup the action is without undulations, while with the other the undulations are quite marked.

To investigate the action of endosmose, a very irregular open circuit battery was employed, consisting of a solution of bichromate of potassium and sulphuric acid, into which were plunged a piece of carbon and a porous cup containing zinc surrounded by mercury. In the action of a galvanic battery there are three separate actions which take place:

1st. A decomposition of the electro-positive ion at the positive electrode.

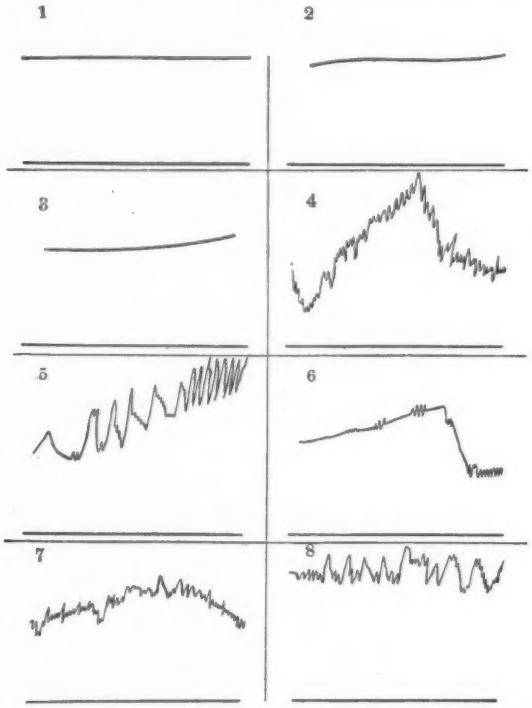
2d. A decomposition of the electro-negative ion at the negative electrode.

3d. The electric current carries whatever comes in its way from the positive to the negative electrode.

It is this last which is called endosmose, and which we wish to investigate.

It was discovered by Breda and Logeman that in a continuous liquid this third action disappeared, and only when a porous partition was introduced was this phenomenon observed. This agrees with the above stated theory; for no such fluctuations

are observed in single fluid batteries. The laws which govern this action were very carefully studied by Wiedemann. Owing to this transporting force the heights of the liquid on the two sides of the porous jar are different, being higher on the side which is nearest the positive electrode. When a strong current acts, more liquid is driven through the partition than with a weak current; moreover, the greater the resistance of the liquid, the more is driven through. From this we find that the



porous jar increases the base or metal transported to the negative pole, and diminishes the quantity of acid at the positive pole in the case of sulphuric or nitric acids. Again, if we increase the surface of the jar, the force tending to transport the liquid is diminished, but it is increased if we increase the thickness or density of the partition.

If now we have a strong current, and a small, thick cup, there will be a maximum force tending to drive the liquid and base from the positive pole, and a consequent decrease in the strength of the current. The first case is well exemplified in

figure 4, in which the fluctuations are very marked. The cup used was very small and dense. Figure 3 shows the action of a cell of ordinary unglazed paper of large dimensions. The current, which was as nearly as possible of the same strength as in figure 4, is perfectly uniform. Figure 1 is a photograph of the action of a cell made of a paper known as parchment paper. We again find a regular action. Wishing to make a slightly more dense cell, one was constructed of parchment of the same size as those employed above. The action of the battery with this cell is shown in fig. 6. It will be noticed that very slight fluctuations occur at the beginning, and in parts of the line.

Figure 7 shows the action of a cell presenting a large surface, but made of very dense earthenware. In this way great advantage is gained, for if the cell had been of the ordinary size, its fluctuations would have resembled those in figure 4.

We can, therefore, say that there are two causes of irregularity in the action of galvanic batteries, and that both difficulties are overcome by making a partition of as large surface dimensions as possible, and by using very porous material.

Jefferson Physical Laboratory.

ART. V.—*On the Sensitiveness of the Eye to Colors of a Low Degree of Saturation;** by EDWARD L. NICHOLS, Ph.D.

[Read at the Philadelphia meeting of the American Association for the Advancement of Science.]

EVERY one who has had occasion to mix colors has noticed that an exceedingly small amount of any pigment will impart its hue to a very large quantity of white. One part of red lead, for instance, will color a million parts of a white powder like the carbonate of magnesium, and even a smaller proportion than that is distinguishable by the average observer, as will appear from the experiments to be described in this paper.

This observation is strikingly at variance with the results obtained by other methods of mixing colors. It has been shown, for example, by Aubert† that a disk, less than $\frac{1}{360}$ of which is painted (radially) with any pigment, the remainder being white, cannot when in rotation be distinguished from an entirely white disk.

We have attempted to measure the sensitiveness of the eye in this respect, by determining the smallest proportion of various coloring matters which, when mixed with a white powder, will

* This is one of a series of researches on the special senses by E. H. S. Bailey and E. L. Nichols.

† Rood: Modern Chromatics, p. 39.

give it a perceptible tint. The pigments selected were red lead, chromate of lead, chromic oxide and ultramarine blue. These were in the form of powder, the red and blue being the red lead and artificial ultra-marine of commerce, whereas the chromium compounds were freshly prepared by precipitation. Each of these pigments was mixed with white in the following manner. About ten cubic centimeters of the powder was mixed in the dry state with an equal volume of magnesium carbonate, the mixture was divided into two equal parts, half of it was again mixed with its own volume of the white powder, the product was again subdivided and the process of mixing with white by equal parts was repeated until all traces of color had disappeared. Since at each stage of the process only half the material was used for further dilution, there remained a series of colored powders of which the pure pigment formed the first, while the succeeding numbers were of less and less saturated hue, and finally could not be distinguished from white. These mixtures were put into small vials of white glass and labelled in such a manner as to ensure their recognition by persons acquainted with the code and at the same time to preclude the detection of the nature of their contents from the label, without such knowledge.

For the purpose of ascertaining the degree of saturation at which the presence of these pigments becomes perceptible to the eye, the four sets of bottles, containing mixtures of red and white, yellow and white, green and white, and blue and white, were mingled indiscriminately, and the observer whose eye was to be tested was requested to arrange those in which he could detect any trace of color, according to hue and degree of saturation. The bottles were afterwards inspected by some one acquainted with the code of labels, who threw out those not in the proper set and recorded the number of bottles remaining in each set and the number of each color which had been properly placed as to shade. From the former record the sensitiveness of the eye to colors of low saturation was determined; the latter data served to indicate the ability of the observer to detect small differences of shade.

Fifty four persons, all of them with two or three exceptions between the ages of fifteen and thirty, were examined in this way. The Holmgren worsteds had shown one of them to be completely green blind, three partially so and one partially red blind. Color-blindness was not found to affect in any marked way their ability to classify the colors.

This method of measuring the sensitiveness of the eye is not in all respects satisfactory. A method in which pure spectral tints mixed with white light could be compared with a field illuminated by white light alone and the amount of monochro-

matic light lessened until its effect was lost to the eye, would certainly be better; but ease and rapidity of execution were essential where so many individuals were to be tested and where the time of those who kindly presented themselves for the purpose was limited. Moreover, the study of spectral tints would not give results directly applicable to pigments, and it is the latter with which we have to do in many practical problems in the science of chromatics. An exhaustive study of this subject would involve the use of both methods.

Table I gives the general results of the fifty-four tests. The averages for males and for females are given separately for purpose of comparison. The numbers indicate in each case the amount of coloring matter present in one hundred million volumes of white, in the most dilute mixture which can be distinguished from a pure white by the average observer.

TABLE I.

Number of parts of coloring matter that must be mixed with 100,000,000 parts of white in order to affect the tint of the compound.

	Red lead.	Chromate of lead.	Chromic oxide.	Ultramarine
Average for 31 males.....	15·9	17·3	817·7	148·5
Average for 23 females	59·8	33·2	913·6	108·1
Average for both sexes....	25·2	23·9	864·2	126·5

The popular impression that in woman the special senses are more finely organized and delicate than in man,* a view considerably strengthened so far as color-perception is concerned by her well authenticated exemption from color-blindness, finds no support from these experiments. As will be seen from the above table the average male observer is measurably more sensitive to red, yellow and green, while the female shows superiority in the blue alone. Quite as interesting, perhaps, is the manner in which the relative sensitiveness of the eye varies with the wave-length. If the corresponding data for mixtures of white and monochromatic light were obtainable it would be possible to indicate by curves the variations of the sensitiveness of the eye in this particular. The light reflected by pigments, however, is so far from being monochromatic† that it is out of the question to attempt to assign them any place in a pure spectrum, and curves constructed upon the assumption that pigments are representative of definite wave-lengths would be of interest only as illustrating in a very imperfect way the general character of the curves which might be obtained by a more precise method.

* Some experiments upon the sense of smell, carried on at the same time as and partly in connection with the tests described in the present paper, indicate that in the case of many common odors also, delicacy of perception is much more marked among men than among women. (E. H. S. Bailey: Proceedings of the Kansas Acad. of Sciences, 1884.)

† See "A spectro-photometric study of pigments," American Journal of Science, vol. xxviii, Nov., 1884.

The variation from these averages, in the case of individual observers, was very marked. Of the fifty-four persons tested, eight (five males and three females), could distinguish the presence of yellow in a mixture of three parts of that pigment in one hundred millions, while two individuals, both of them females, failed to detect it in mixtures containing less than one hundred and ninety parts in one hundred millions. Like differences were met with in the sensitiveness of the eye to other colors, and the relative sensitiveness to different colors was not the same for all observers.

The lack of delicacy in respect to green was a very general trait. Only three observers were as sensitive to green as to blue, and in the case of but one individual was the power of detecting the former color equal to the sensitiveness to yellow. The thought suggests itself that the failure to detect green may be due to a blunting of the nerves which respond to that color by continual exposure to green foliage. An investigation of the relation between the sensitiveness of the eye to colors mixed with white and the form of the three primary color-curves of the eye would add to our knowledge of this subject.

The striking discrepancy between these results and those obtained by the method of rotating disks, the eye recognizing with ease and certainty one part of coloring matter in many millions when mechanically mixed with white, and failing to detect one part in a few hundred parts (i. e., 360 parts) when mixed by rotation, shows, in our opinion, that the eye while watching a revolving disk is in an abnormal condition, and that quantitative results obtained by this favorite method of combining colors are not always comparable with those which we get by the actual mixture of white and colored light, or by the mechanical mixture of pigments. In view of the large number of researches upon Chromatics and Physiological Optics in which the revolving disk has been used, a special study of the condition of the eye during the observation of the disk, and a comparison of the results of this method with those obtained in other ways is greatly to be desired. In this manner alone can the limits of usefulness of this exceeding simple and convenient method be determined.

The tests of the power of recognition of small differences of shade were undertaken chiefly as a further means of comparing the attainments of the sexes in delicacy of color perception. The method was not adapted to the direct determination of the smallest difference of saturation which can be perceived, but our experience with the series of colors already described showed that the neighboring members were quite as closely allied in shade as was compatible with their recognition. Indeed, of fifty-four observers not one succeeded in placing all

the vials, the colors of which were perceptible to him, in their proper places in the series. The two nearest approaches to complete accuracy consisted in the correct arrangement of ninety bottles out of ninety-two in the one case and of ninety out of ninety-three in the other. Although these records were made by male observers, the *average* for the other sex was noticeably higher than that of the males. It was found that of all the mixtures possessing appreciable color the average observer of each sex placed the following proportions correctly:

TABLE II.

Average accuracy of male and female observers in detecting the degree of saturation of mixtures of pigments with white. (Complete accuracy would be indicated by 100·00.)

	Red lead.	Chromate of lead.	Chromic oxide.	Ultramarine.
Males	86·86	87·16	92·81	78·13
Females	90·81	93·24	98·28	82·92

A comparison of tables I and II shows that the color (green) to which the eye is least sensitive, so far as the ability to detect small amounts of color is concerned, is the one in which the least difficulty is met with in noticing differences of shade. Possibly the circumstance already suggested as the cause of the deficiency in the one respect, i. e., continued exposure and consequent loss of sensitiveness to green, may be looked to as the cause of the increased facility in the other. If the detection of colors of low saturation depends upon the *delicacy* of the eye and the recognition of differences of shade upon *practice*, it would account equally well for both peculiarities.

An examination of some of the mixtures used in the foregoing tests under a half-inch objective magnifying about two hundred diameters, showed that the pigments consisted of well-formed, glistening crystals about $\frac{1}{100}^{mm}$ in diameter. These crystals were mingled with the magnesium carbonate without imparting *any trace* of their own color to the latter. Under the microscope the separation was perfect and the contrast of color a striking one. In the more dilute mixtures it was often necessary to search for some time before a single crystal of the pigment could be found, and the portion placed upon the slide did not contain, in some cases, more than five or six crystals altogether. To the naked eye, nevertheless, the mass appeared perfectly homogeneous, and unmistakably colored. Doubtless the power of a few isolated points of color, too small to be recognized individually by the eye, to impart their own hue to the entire colorless field in which they lie, is due to the persistence of the color-impression they produce upon the retina; this impression being fused with the impression of white from the remainder of the field of view by the continual movement of the eye in the process of observation.

University of Kansas, July, 1884.

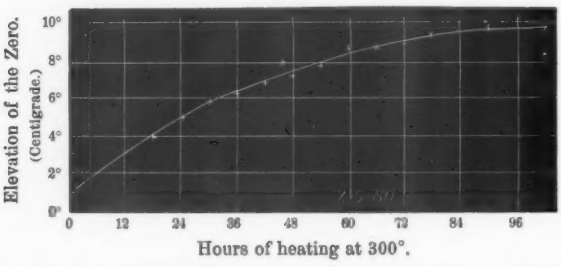
ART. VI.—*A Study of Thermometers intended to measure Temperatures from* 100°–300° *C.*; by O. T. SHERMAN.

IT is well known that when a thermometer is heated above a certain point, the mercury column is permanently displaced with regard to the scale.* The position of the point depends upon the constitution of the glass forming the bulb and upon the previous use of the thermometer. For certain glasses designated by the maker as German or American soda and Cornish the elevation upon a new thermometer begins at 111°. For a flint or crystal tube the point is nearer 200°. Mills records 256° as his highest observed limit, 48° as his lowest. Our experience presents nothing lower than 110°, nor higher than 255°. The latter point is obtained with English flint or French crystal.

By much use or long heating the displacement frequently amounts to ten degrees Centigrade, and may amount to 26°.† To assign corrections to points so easily displaced is evidently nugatory. The Observatory has therefore hitherto confined its corrections to points below that at which the ascent began.

If now the thermometer be exposed to a high temperature for some hours, the successive positions of the ice-point will be found to arrange themselves in a curve similar to that in the adjoining figure. Thus, for the first eighteen hours dur-

1.

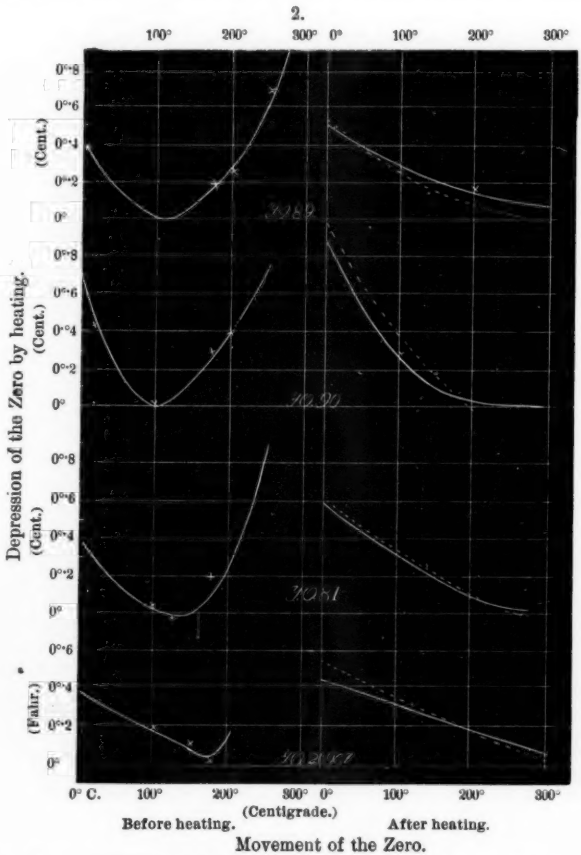


ing which the thermometer Y. O. 80 was held at 300° Centigrade, the zero point was elevated 3°; for the second eighteen hours the elevation was 2°·2; for the succeeding periods 1°·7, 1°·1, 0°·8, 0°·3 respectively.‡ The elevation evidently becomes less and less, and the curve becomes more nearly parallel to the axis of abscissas. This same thermometer placed in a bath at 200° immediately after the last observation rose two-tenths of

* Mills, Transactions Royal Society of Edinburgh, vol. xxix, part II.
† Crafts, Comptes Rendus, 1881 and 1882.
‡ Weber, Metronomische Beitrag, No. 111, pp. 126, 127.

a degree in the first twelve hours, but no change was detected in the following hundred and eight.

The question presents itself, What is the state of the thermometer after such treatment? First, as regards the action of the zero. In the adjoining cut we have compared the motion of the zeros of four thermometers before and after treatment.



Movement of the Zero.

In the first series the influence of the rise is evident. The second series is free therefrom. The movement of the zero for the higher temperatures is similar to that for lower; or the mere fact of heating the thermometer now produces no distortion from which the instrument will not sensibly recover.

Does the instrument after treatment repeat its readings when exposed to similar conditions? Do its indications vary with

time? We have observed the corrections to the following treated thermometers on Feb. 16th, March 9th and 22d, and April 15th. The record is given in the adjoining table:

	Feb. 16.	March 9.	March 22.	April 15.	Feb. 16–April 15.
	Y. O. 81 (Cent.).				
0°	−6°·6	−6°·6	−6°·5	−6°·5	
100°	−5·85	−5·78	−5·76	−5·68	−0·16
200°	−6·3	----	----	−6·1	
	Y. O. 89 (Cent.).				
0°	−5°·5	−5°·5	−5°·5	−5°·5	
100°	−4·1	−4·0	−4·1	−4·0	−0·1
200°	−5·3	----	----	−5·1	
	Y. O. 90 (Cent.).				
0°	−8°·9	−8°·9	−8°·6	−8°·5	
100°	−6·8	−7·0	−7·0	−6·9	−0·06
200°	−6·3	----	----	−6·4	
	Y. O. 20967 (Fahr.).				
0°	−16°·8	−16°·9	−16°·9	−17°·0	
212°	−18·6	−18·4	−18·6	−18·5	
387°	−25·2	−25·2	----	----	+0·17
420°	−27·8	----	----	−28·2	

On all of these instruments the closeness of the graduation renders an error of observation of a tenth not improbable, so that, with one exception, there is no difference which seems worthy of remark.

These observations indicate that after treatment the thermometer is as serviceable as a measure of temperature ranging from 0° to 300° C. as the standard to which we are accustomed is for the range 0° to 100°. In the curves representing the movement of the zero, the record of April 15th is represented by a dotted line, that of Feb. 16th by the full line. The former are slightly more curved than the latter. Again, in the final column of the preceding table are given the mean differences between the corrections due to Feb. 16th and April 15th. Both of these differences we would interpret as small effects still occurring in the bulb, such as occur in every new thermometer, rather than as evidence that the instrument does not repeat itself.

It is of interest to ask what is the nature of the change which has been effected in the glass. If we compare the errors before and after treatment, we obtain the following differences:

	Y. O. 81.	Y. O. 89.	Y. O. 90.
0°	4°·0	4°·9	7°·5
100°	2·8	2·9	6·6
200°	4·6	4·0	4·4

The differences for Y. O. 20967, upon which the points of comparison are more frequent, are given in the adjoining curve.

These differences indicate a change in the coefficient of ex-

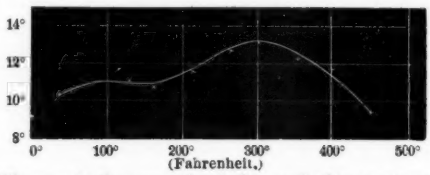
pansion of the glass. The amount for the interval 0°–100° is readily calculated, and presents us with the following values:

Y. O. 81.....	100. $\delta\beta$	$= -0{\cdot}000046$
Y. O. 89.....		$= -0{\cdot}000022$
Y. O. 90.....		$= -0{\cdot}000003$
Y. O. 20967..		$= +0{\cdot}000026$

Values similar to the first two have been previously observed by Weber and by Crafts. The latter two are, as far as my knowledge goes, without precedent.

Again, if the thermometer be preserved at ordinary temperatures, similar changes occur. We may instance the elevation of the zero with time. Its law is similar to that of the elevation produced by heating; or, analogies occur in the change in the fundamental length and the indicated change in the coefficient of expansion.

3.



Difference in the correction before and after treatment.

All of these facts—the condensing of the material forming the bulb, the consequent increase of its intermolecular attraction, the dependence of the point of rising upon its chemical constitution, the similarity of the changes produced by time, the regularity of these changes—seem to indicate the cause for the one as was long since suggested for the other, in a partial separation of the crystalline from the amorphous bulb-constituents. If the view is correct, it argues well for the stability of the treated instrument. The change will have been produced at the expense of its natural life. But then, few thermometers are permitted to die of old age. The correctness of the view is the subject of a separate research.

Yale College Observatory, April, 1885.

ART. VII. — *Notice of a new Limuloid Crustacean from the Devonian;* by HENRY SHALER WILLIAMS.

AMONG the fossils collected last summer for a comparative study of the Devonian faunas, an interesting form was discovered in Erie County, Pennsylvania, worthy of special notice.

The specimen was found in the bluish sandstone (which in places is a fine pebbly conglomerate) at Le Bœuf, called the "3d oil sand" by Mr. I. C. White in the Report Q⁴ of the Second Geological Survey of Pennsylvania (p. 239), and re-

garded by him as the equivalent of the third oil sand of the Venango oil district of that State. In the same stratum and above it are typical Chemung fossils.

It occurs just at the junction between the sandstone and a stratum of soft, fine argillaceous shale, and, in the process of weathering, the fine shale has been washed away, leaving a sharply defined cast of the fossil in hard sandstone, though no portion of the original crust is preserved.

The associated species are *Spirifera Verneuilii* Murch. (=*Sp. disjuncta* Sow.), and *Rhynchonella contracta* Hall; and in the shales just above the sandstone occur *Chonetes scitula* Hall, "*Chonetes*" *muricata* Hall, an *Ambocoelia umbonata* Hall, a small Productus of the type of Hall's *Productella Boydii*, the coarse ribbed *Orthis Leonensis* Hall, and a Rhynchonella agreeing with some of the wider forms of *R. sappho* Hall.

The fauna is the characteristic Upper Chemung fauna of western New York and adjacent area. In this area some of the species occur among the earliest Chemung species; no characteristic Carboniferous types have been detected. The fauna may be considered, therefore, as a pure Devonian fauna.

The general form and structure of the specimen place it among the Merostomata with anchylosed thoracico-abdominal segments, but as only the under side is exhibited, its identification with *Prestwichia* must be regarded as provisional, since we are ignorant of the structure of the under surface of authentic members of that genus.

I propose as a name for it,

Prestwichia Eriensis, sp. n.

The following characters exhibited by the specimen are regarded as generic and as locating it in the genus Prestwichia of Woodward: (1), the elliptical head shield; (2), the genal spines which proceed backward more directly than in any described species of the genus; (3), the thoracico-abdominal segments anchylosed to form a buckler, to which is attached (4) a long telson. The general outline of the whole animal resembles that of the modern Limulus.

The evidence of a solid thoracico-abdominal buckler is found in the continuous surface across the body, from which proceed four (visible) short marginal spines each side the telson, and upon which are seen at least eight narrow ridges running longitudinally to near the margin.

The remaining characters may be, in part, of generic value, but they constitute the distinctive characters of the species, as far as these can be made out from the specimen.

The under side of the body presents three well defined tracts, viz: (A B), the cephalic shield which is evenly rounded in front and is laterally prolonged backward into two genal

spines (C), which are nearly parallel with the axis of the body and reach nearly to a point opposite the posterior margin of the buckler. The cephalic shield along the median line is about a third the length of the body; (M K) the space between the posterior margin of the cephalic shield and the anterior margin of the buckler containing the region of the mouth (M) and the gnathopods (K), and (F D H) the thoracico-abdominal buckler, marked over the surface by longitudinal ridges and by marginal spines, and terminating in a long stout telson (E). Traces of the gnathopods are seen, as also traces of the foliaceous appendages of the posterior pair (L), but in too imperfect condition for exact delineation. Just anterior to the position of the mouth is seen a shield-like elevation (B), upon the edge of the cephalic shield, which has the appearance of an hypostoma. The condition of the specimen is not such as to give absolute certainty to this interpretation, though the symmetry of its form is strongly in favor of it. It is possible that it is merely outlines upon the surface produced by crushing during fossilization. There are faint indications of joints on each of the anterior set of gnathopods (K K).

Along the center of the thoracic region (H), there is a flattened depression, traversing longitudinally from the anterior edge of the plate F, backward to the middle of the telson E.

The terminal portion of the telson is evenly rounded. Each side of the median line of the buckler there are visible four clearly defined marginal spines (*g g*); there were probably more of them—six I have supposed, as in fig. 3, but concealed in the specimen by the filling between the buckler and genal spines.

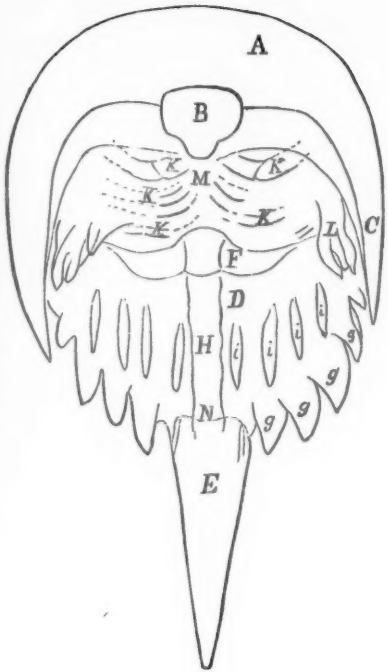
There are also four rounded, longitudinal ridges on the buckler each side of the flattened depression H; these (*i i*) begin abruptly near the anterior margin of the buckler and run almost directly backward, tapering to a slender point near the margin of the buckler.

At the anterior margin of the buckler there is a narrow plate, divided into a median and two lateral parts (F), which appears to be separated from the buckler itself by a distinct furrow. Laterally this plate appears to curve inward and lies below (within) the surface of the buckler, and the median portion extends forward to a blunt point. I have interpreted this as probably representing the consolidated lamellar appendages of the "first and second" thoracic segments of Eurypterus, as defined by Hall in Paleontology of New York, vol. iii, p. 398.

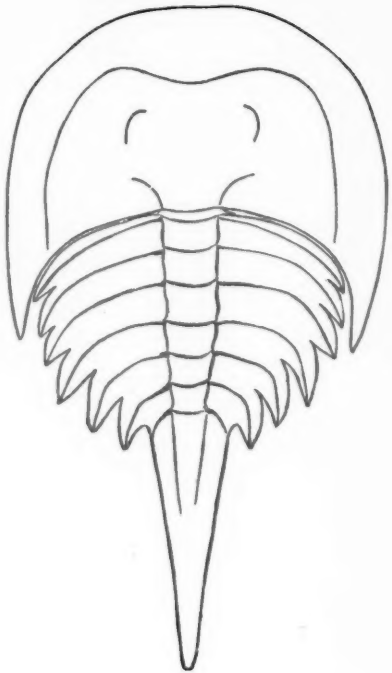
The telson E, is nearly two-thirds the length of the body, is flattened at the base, but nearly cylindrical and tapering to a blunt point at the extremity. There is no indication of its articulation, but there is no reason, from the condition of the specimen, to presume that it was not articulated.

1.

2.



3.



Prestwichia Eriensis—H. S. Williams.

Above are given all the characters of which the specimen presents any reasonable suggestion. I have ventured to put an interpretation upon some of the characters for which the evidence is slight in the hope that those possessing specimens of any kindred forms may throw light upon this one by confirming the interpretation here given or suggesting a better one.

Fig. 1 represents very fairly the actual appearance of the specimen in size and details. It is a photo-engraving from a drawing of the original and photographs of it made by Professor E. C. Cleves of Cornell University.

Dimensions—Total length ..... 10· cm
Greatest width ..... 5·7
Length of telson (about) ..... 4·
Length of buckler (about) ..... 2·
Greatest thickness of telson ..... 0·7

Horizon—Chemung Group, Upper Devonian; the "third oil sand" of I. C. White, 2d Pa. Survey.

Locality—LeBœuf, Erie County, Pennsylvania.

The original specimen is among the collections of the U. S. Geological Survey, and will be deposited ultimately in the National Museum.

Comments.—This specimen throws back the known range of *Prestwichia*, or at least the type to which this genus belongs, to an earlier stage than heretofore reported. The earliest previously known *Prestwichia* occurs in the Carboniferous.

If my interpretation of its characters be correct, Prestwichia bears closer relations to Limulus than is suggested by other known specimens, and also it possesses features linking it with Trilobites and Eurypterids.

EXPLANATION OF FIGURES.

FIG. 1. *Prestwichia Eriensis* Williams, sp. n. A sandstone cast representing the under surface; natural size.

FIG. 2. Diagram of the same.

A. Cephalic shield.
B. ? Hypostoma.
C. Genal spines of the cephalic shield.
D. Thoracico-abdominal buckler.
E. Telson.
F. First (and second?) segments of thorax (? anchylosed).
Gg. Marginal spines of the buckler.
H. Flat median depression extending across the buckler and upon the telson.
ii. Longitudinal ridges of the buckler.
KK. Portions of the gnathopods.
L. ? Foliaceous terminations of the last gnathopods.
M. Position of the mouth.
N. Probable place of articulation of the telson.

FIG. 3. Theoretical diagram of upper side.

Cornell University, April, 1885.

Art. VIII.—*Gerhardtite and Artificial Basic Cupric Nitrates*, by H. L. Wells and S. L. Penfield.*

We shall describe in the present article a natural, crystallized basic cupric nitrate and a crystallized artificial salt of the same chemical composition but of different crystalline form. We also give an account of a re-investigation of two basic cupric nitrates to which have been ascribed different compositions, but which, as we shall show, have the same composition as the basic nitrates described by us and by other investigators, whose results will be briefly summarized.

Gerhardtite, *a new mineral.*

This mineral was first identified as a new species by Prof. Geo. J. Brush, who found it among a lot of copper minerals from the United Verde Copper Mines, Jerome, Arizona, which were left at the Sheffield Scientific School by Mr. G. W. Stewart, assayer, from that place.

The single specimen in our possession consists of a small piece of very pure massive cuprite, along a crack in which the crystals of the nitrate occur, together with acicular crystals of malachite. The crystals, 4–6^{mm} in diameter, were few in number and were almost wholly sacrificed to obtain material for investigation. An attempt has been made to obtain more of the material, but as yet no other specimens have been received, although we are in hopes that more may be found at the locality. From the abundance of crystals on the specimen in our possession, it would seem that there must have been a quantity of it found. It was probably regarded as malachite by the miners. Another specimen contains crystals of atacamite on the cuprite.

The crystals, which were carefully separated from the cuprite, were subjected first to crystallographic, then to chemical examination. About 0·8 of a gram was obtained almost perfectly pure, the only impurity being a few acicular crystals of malachite which sometimes penetrated the nitrate but were visible only under the microscope.

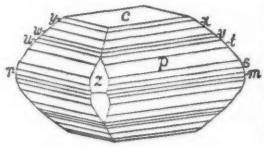
The hardness of the mineral is 2. Specific gravity 3·426. Color dark green. Streak light green. Transparent.

The crystals after being detached were only fragmentary. All those suitable for measurement were reserved. They were very fragile and had to be separated and handled with very great care. The crystals are orthorhombic, having the habit shown

* The chemical work is by the former, the crystallographic by the latter.

in fig. 1. There are two cleavages, which serve for orientation, one basal, parallel to *c*, as perfect as the most perfect cleavage of gypsum, a second, less perfect, parallel to the macropinacoid. The crystals can be readily bent, in which case they crack and separate along the latter direction. The most prominent forms on the crystals, besides the basal plane, are a series of pyramids occurring in oscillatory combination, which makes their indentification somewhat difficult. The best measurements were obtained from a small but very perfect macrodome which was found on two crystals. Owing to the fragmentary nature of the crystals and the difficulty of identifying the pyramidal planes, their orthorhombic form might be doubted were it not for their optical properties.

1.



The axial ratio was obtained from the following measurements:

$$c \wedge z \quad 001 \wedge 201 = 68° 16'$$
$$z \wedge p \quad 201 \wedge 111 = 39° 3' 30''$$

giving $\breve{a} : b : \dot{c} = 0{\cdot}92175 : 1 : 1{\cdot}1562$

The following forms were observed:

c,	001,	*O*	*t*,	778,	$\frac{7}{8}$
z,	201,	$2\text{-}\bar{1}$	*u*,	334,	$\frac{3}{4}$
m,	110,	*I*	*v*,	7·7·10,	$\frac{7}{10}$
r,	551,	5	*w*,	223,	$\frac{2}{3}$
s,	221,	2	*x*,	13·13·20,	$\frac{13}{20}$
p,	111,	1	*y*,	112,	$\frac{1}{2}$

The following is the table of measured and calculated angles, the measurements being made on eight crystals, the number of times each form was measured being given.

		Calculated.	Measured.	No. of times.
$m \wedge m$	$110 \wedge 1\bar{1}0$	85° 20′		
$z \wedge z$	$201 \wedge 20\bar{1}$	43° 28′	43° 34′	1
$c \wedge m$	$001 \wedge 110$	90°	90° 15′–90° 25′	2
$c \wedge r$	$001 \wedge 551$	83° 19′	83° 1′	1
$c \wedge s$	$001 \wedge 221$	73° 40′	73° 53′	1
$c \wedge p$	$001 \wedge 111$	59° 37′	59° 23′–59° 57′	6
$c \wedge t$	$001 \wedge 778$	56° 11′	55° 57′–56° 19′	3
$c \wedge u$	$001 \wedge 334$	51° 59′	51° 52′–52° 20′	2
$c \wedge v$	$001 \wedge 7710$	50° 3′	49° 46′–50° 38′	3
$c \wedge w$	$001 \wedge 223$	48° 40′	48° 8′–49° 12′	8
$c \wedge x$	$001 \wedge 13{\cdot}13{\cdot}20$	47° 57′	47° 11′–47° 56′	5
$c \wedge y$	$001 \wedge 112$	40° 28′	40° 13′–40° 18′	2
$x \wedge x$	$13{\cdot}13{\cdot}20 \wedge 13{\cdot}\bar{1}\bar{3}{\cdot}20$	60° 27′	60° 9′	1

Only distinct reflections were recorded, though other forms seemed to be present but were not definite enough to be determined. The variation in the measurements is large and may be due in part to an accidental bending of the crystals. The

forms x and v with improbable indices would have been regarded as accidental had they not occurred repeatedly giving very distinct reflections. Tabular fragments, parallel to the basal cleavage, show under the polarizing microscope an extinction parallel to the macro-diagonal cleavage lines and in convergent light a bisectrix normal to c, 001. The optic axes lie in the brachypinacoid, the axial angle is large and could not be measured in air. Measured in the heavy solution of HgI_2 in KI (n=1·703 for yellow, 1·722 for green).

$2H = 76°\ 20'$ for yellow.
$2H = 80°\ 4'$ for green.
Dispersion $\rho < v$.

A very thin section had to be used to obtain the character of the dispersion as moderately thick sections were practically opaque to yellow light. The indices of refraction could not be determined owing to the want of suitable material, the Kohlrausch total-reflectometer giving no total reflection.

Double-refraction is strong, negative.

Pleochroism is distinct:

For vibrations parallel to c, $\breve{a}$ blue.
" " " " b, $\bar{b}$ green.
" " " " a, $\dot{c}$ green.

Chemical composition.—Qualitative examination showed only the presence of CuO, N_2O_5 and H_2O.

I. ·3975 gram yielded ·0457 H_2O and ·2634 CuO.
II. ·3986 gram yielded ·0449 H_2O, ·2646 CuO, and 19·7 cc. dry N at 12·8° and 759 mm. (cor.).

	Found. I.	II.	Calculated for $4CuO . N_2O_5 . 3H_2O$.
H_2O	11·49	11·26	11·56
CuO	66·26	66·38	66·22
N_2O_5	22·25*	22·76	22·52
	100·00	100·40	100·00

Pyrognostics, &c. B.B. fuses at 2, coloring the flame green. With soda on coal easily reduced to metallic copper with deflagration. In closed tube gives nitrous fumes and water which reacts strongly acid. Soluble in dilute acids, insoluble in water.

It is somewhat surprising that a mineral of this composition has not been found before, owing to the occurrence of nitrates in natural waters, the stability and insolubility of the compound and the ease with which it is made artificially.

* By difference.

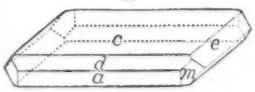
We propose for this beautiful and unique mineral, the only insoluble nitrate yet found in nature, the name Gerhardtite from the chemist who first determined the true composition of the same compound* made artificially.

Crystallized Artificial Basic Cupric Nitrate.

This is made by heating a solution of the normal nitrate with metallic copper in a sealed tube to about 150° for a day or more. The crystals form just above the surface of the liquid on the walls of the tube. When the contents of the tube are agitated the crystals fall to the bottom of the liquid where they remain undissolved while another crop is being formed. Cupric nitrite is apparently one of the products of the reaction: consequently the method is essentially a modification of that used by Vogel and Reischauer† in making the same compound in light, iridescent scales.

The crystals are of a beautiful dark green color, exactly the same as that of the mineral, with a very brilliant luster. Specific gravity 3·378. The largest which we succeeded in making were 7 or 8^{mm} in length. Their form is monoclinic as is shown both by measurement and by their optical properties. Their habit is tabular, lengthened out in the direction of the b axis, fig. 2. The axial ratio was determined from the following measurements:

2.



$$c \wedge a \ 001 \wedge 100 = 85° 27'$$
$$c \wedge d \ 001 \wedge 101 = 48° 25\tfrac{1}{2}'$$
$$e \wedge e \ 011 \wedge 01\bar{1} = 82° 41'$$

giving $\quad \dot{a} : b : \dot{c} = \cdot 9190 : 1 : 1\cdot 1402 ; \quad \beta = 85° 27'$

The observed forms are

a,	100,	i–$\bar{i}$	d,	101,	1–$\bar{i}$
c,	001,	O	e,	011,	1–$\dot{i}$
m,	110,	I			

The following are the measured and calculated angles.

		Calculated.	Measured.
$m \wedge m$,	$110 \wedge 1\bar{1}0$	84° 59′	
$a \wedge m$,	$100 \wedge 110$	42° 29′	42° 36′
$c \wedge m$,	$001 \wedge 110$	86° 39′	86° 30′
	$00\bar{1} \wedge 110$	93° 21′	93° 40′
$c \wedge e$,	$001 \wedge 011$	48° 39′	48° 39′

Two twin crystals were found. They were not very perfect but the reëntrant angle $a \wedge a$ could be measured giving 9° 6′, calculated 9° 6′.

It may be said of the measurements on the prism m, that the face was usually quite imperfect and did not admit of very ac-

* See beyond. † See beyond.

curate measurement. Many trials were made before crystals suitable for measurement were obtained and a few crystals only were selected, which although small were very perfect. Many of the crystals have a different habit from that given in fig. 2, being terminated at the extremity of the b axis by the prismatic faces only, but none were found which admitted of measurement.

The cleavage is basal, perfect, a second cleavage is parallel to a (100). The crystals are brittle but do not bend like those of the natural nitrate.

Under the polarizing microscope the crystals show an extinction parallel to the b axis. In convergent light the axes are seen to lie in the plane of symmetry. One axis is visible in the field of the microscope, inclined about 40° to a normal to the basal plane, the other axis is outside of the field of the instrument. The bisectrix lies in the obtuse secant; its inclination could not be determined. One of the largest tabular crystals showed one axis in the axial angle apparatus, the other was totally reflected. In the solution of HgI_2 in KI (n=1·703 for yellow, 1·722 for green) both axes could be seen showing a marked inclined dispersion $\rho < v$, the axial angle being

$2H = 59° 22'$ for yellow.
$2H = 63° 50'$ for green.

Double-refraction, negative.

Pleochroism as in the orthorhombic crystals: $\parallel b$ green.
$\perp b$ blue.

The crystals of the natural and artificial compound are very much alike, making a very interesting case of dimorphism. The points of similarity are repeated below.

Orthorhombic, natural, $\breve{a} : \dot{b} : \dot{c} = 0{\cdot}92175 : 1 : 1{\cdot}1562$
$\beta = 90$

Cleavage 001 and 100

Monoclinic, artificial, $\breve{a} : \dot{b} : \dot{c} = 0{\cdot}9190 : 1 : 1{\cdot}1402$
$\beta = 85° 27'$

Cleavage 001 and 100.

Plane of the optic axes in the brachypinacoid in the former and in the corresponding plane of symmetry in the latter. Dispersion almost of the same amount and $\rho < v$ in both cases. Double-refraction negative, and pleochroism similar with almost identical shades of color in both.

Chemical analysis:

I. 1·2373 grams yielded ·1388 H_2O and ·8202 CuO.
II. ·5314 gram yielded ·0615 H_2O, ·3519 CuO, and 25·4 cc. dry N at 12·9° and 764 mm. (corrected).

	Found. I.	II.	Calculated for $4CuO.N_2O_5.3H_2O$.
H_2O	11·23	11·57	11·26
CuO	66·29	66·22	66·22
N_2O_5	22·48*	22·10	22·52
	100·00	99·89	100·00

Artificial Basic Cupric Nitrate made by other methods.

Graham† investigated a compound made by heating normal cupric nitrate. His formula was incorrect, owing to the fact that he merely determined cupric oxide and volatile matter, and, consequently, had insufficient data for determining it.

Gerhardt‡ showed the true composition of Graham's compound to be $4CuO.N_2O_5.3H_2O$. He made it a number of times under varying conditions and always obtained analytical results corresponding to this formula. He also showed that the precipitate formed by adding ammonium hydroxide not in excess to a solution of the normal nitrate has the same composition.

The following investigators have since confirmed Gerhardt's results: Gladstone§ by analysis of the compound made by heating the normal nitrate; Kühn‖ by examination of the precipitate formed by ammonium hydroxide; Vogel and Reischauer¶ by investigation of the light, iridescent, blue-green, crystalline scales made by boiling mixtures of the solutions of cupric nitrate and potassium nitrite and also by boiling the deep green solution made by passing nitrous acid gas through water containing cupric hydroxide in suspension; Field,** and Reindel†† by examining the precipitate formed by the addition of potassium hydroxide, not in excess, to solutions of normal cupric nitrate.

On the other hand, Casselmann‡‡ has described a basic nitrate which is precipitated by boiling solutions of cupric nitrate with acetates and various other soluble salts of organic acids and to which he ascribes a composition corresponding to the formula $2(4CuO.N_2O_5)7H_2O$. It will be noticed that this differs from Gerhardt's formula by only $\frac{1}{2}H_2O$; hence we thought it proper to reinvestigate the compound.

Sodium acetate was added to a hot, dilute solution of cupric nitrate until a copious precipitate was formed. The liquid was boiled until the precipitate became dense when the latter was thoroughly washed with cold water. No discoloration of the product was noticed either on boiling or washing, although Cas-

* By difference.
† Phil. Trans., 1837, 57.
‡ Jour. Pr. Chem., xxxix, 136.
§ Idem, xliv, 184.
‖ Jahresber., 1, Engl. transl., p. 340.
¶ Jahresber., 1859, 216.
** Idem, 1862, 216.
†† Idem, 1867, 304.
‡‡ Zeitschr. Anal. Chem., 1865, 24.

selmann states that blackening took place in both instances when he made the compound, so that he was unable to make it pure and unaltered. The product was composed of minute crystals, forming a powder of a light green color. Specific gravity 3·371. The following chemical analysis proves its identity with the basic nitrate made by other methods.

Of the substance, dried over sulphuric acid, 1·0631 gram yielded ·1229 H_2O, ·7035 CuO, and 52·4 cc. dry N at 18·9° and 764 mm. (corrected).

	Found.	Calculated for $4CuO . N_2O_5 . 3H_2O$.	Calculated for Casselmann's formula.
H_2O	11·46	11·26	12·89
CuO	66·17	66·22	64·99
N_2O_5	22·42	22·52	22·12
	100·05	100·00	100·00

A basic cupric nitrate mixed with metalic silver was made by H. Rose* by acting on cuprous oxide with silver nitrate solution. Rose not having determined the composition of the salt, Rammelsberg† attempted to do so and assigned to it a composition represented by the formula $Cu_{10}N_6O_{25}$. This differs so widely from the basic salt made by all other known methods that it was deemed advisable to reëxamine it.

Pure cuprous oxide was made by adding a dilute solution of pure glucose to an excess of Fehling's solution heated just to boiling. The precipitate was thoroughly washed, then treated while still wet with a large excess of silver nitrate solution, the liquid was boiled and the whole allowed to digest on a water-bath for several hours. The resulting dark gray voluminous powder was carefully washed with water and dried at 100°. In some preliminary experiments it was found difficult to completely decompose cuprous oxide after it had been dried, and it was also found that the reaction took place only very slowly in the cold; consequently the above mentioned method for making the mixture was adopted.

Supposing the mixture to consist of a basic cupric nitrate of Gerhardt's composition and metallic silver, the reaction would evidently be as follows:

$$3Cu_2O + 6AgNO_3 + 3H_2O = 4CuO . N_2O_5 . 3H_2O + 6Ag + 2CuN_2O_6.$$

Analysis proved this to be the case.

Of the substance dried at 100°,

I. 1·4958 grams yielded by ignition 1·2848 Ag and CuO,—the latter yielded 1·1459 AgCl.

II. 1·9329 grams yielded 1·6592 Ag and CuO, 1·4791 AgCl, ·0893 H_2O, and 40·55 cc. dry N at 18·2° and 758 mm. (cor.)

* Pogg. Ann., ci, 513. † Ber. Deutsch. Chem. Ges., 1877, 1780.

	Found. I.	Found. II.		Calculated for $6Ag+4CuO.N_2O_5.3H_2O$.	
Ag	57·66	57·60		57·46	
CuO	28·23	28·24	66·68	28·17	66.22
H_2O		4·62	10·91	4·79	11·26
N_2O_5		9·49	22·41	9·58	22·52
		99·95	100·00	100·00	100·00

Graham* states that the basic cupric nitrate will withstand a temperature near that of melting lead without decomposition. We find, on the other hand, that it begins to decompose when heated to 180–200°, blackening and giving off both water and nitric acid. The product made in sealed tubes and that made by Casselmann's method were both subjected to this experiment with like results.

The empirical formula for the compounds under consideration is $H_6Cu_4N_2O_{12}$ or $H_3Cu_2NO_6$. Cooke† developes this to $(HO)_3$, $(CuO_2H)_3$, CuO_2, viii, N_2O. A simpler formula is $H(HOCu)_2NO_4$. The latter has the argument in its favor that some other basic nitrates can best be formulated as derivatives of the hypothetical acid H_3NO_4 (corresponding to H_3PO_4), but the union of hydroxyl to both acid and basic radicals is possibly an objection to it as well as to Cooke's symbol.

It is an interesting fact that the monoclinic (?) mineral tagilite has the formula $4CuO.P_2O_5.3H_2O$, exactly corresponding to the nitrate.

Method of analysis.

Owing to the small quantity (less than ·8 gram) of the native nitrate at our disposal, it was important to use a method which would give a complete analysis on a single sample. The apparatus having been set up and tested, it was found to be so satisfactory and convenient that it was used for the other analyses given in this article.

The substance was ignited in a boat in a current of pure, dry CO_2 in a combustion-tube. The CuO remaining in the boat was weighed. The gases passed over a hot roll of copper gauze, then through a weighed calcium chloride tube, which absorbed the water, into an azotometer containing a concentrated solution of potassium hydroxide where the nitrogen was measured.

The carbon dioxide was made from crystallized calcite. The removal of the air from the apparatus before the ignition and the collection of the nitrogen afterwards was accomplished by passing the CO_2 only about ½ hour in each case. The CO_2 in the $CaCl_2$ tube was replaced by dry air before weighing.

Laboratories of Chemistry and Mineralogy,
Sheffield Scientific School, June 6, 1885.

* Loc. cit.

† Chemical Philosophy. 379.

ART. IX.—*On the occurrence of Fayalite in the lithophyses of obsidian and rhyolite in the Yellowstone National Park;* by JOSEPH P. IDDINGS, of the U. S. Geological Survey.

THE obsidian which forms the columnar cliff just north of Beaver Lake, on the road from Mammoth Hot Springs to the Geyser Basins, is especially rich in spherulites of various kinds, and of the more or less hollow forms called lithophyses by von Richthofen,* who first described those found in the rhyolites of Hungary.

These lithopyses, which vary in size from less than a quarter of an inch to a foot in diameter, when broken open often appear like spherulites whose central mass has shrunken and cracked apart like the pithy center of an over-ripe watermelon, or are composed of hollow, concentric shells, either hemispherically arranged in rose-like forms, or in segments like the chambers of an ammonite. The walls of these cavities are usually coated with transparent crystals of prismatic quartz and tabular tridymite, both appearing to have been deposited at the same time; scattered among these are small, opaque, black crystals about 2^{mm} and less in length. They are tabular in form, apparently with orthorhombic symmetry, and have most frequently a metallic luster, and sometimes a reddish color; they are found upon examination to be coated with ferric oxide, the interior of the crystals being transparent and of a light yellow color. Their optical behavior between crossed nicols is that of an orthorhombic mineral with high index of refraction, closely resembling olivine.

A chemical analysis was made by Dr. F. A. Gooch of the chemical laboratory of the U. S. Geological Survey, on a small amount of material, 0·24 gram, all that was at the time available. Under the microscope the crystals were seen to carry a small amount of adhering quartz, and to be coated with iron oxide, they were readily decomposed in hot hydrochloric acid with the separation of silica and yielded the following results:

SiO_2	25·61
Al_2O_3	trace
Fe_2O_3	14·92
FeO	51·75
MgO	1·66
CaO	none
Ignition	none
Insol. SiO_2	7·02
	100·96

* F. von Richthofen. "Studien aus den ungarisch-siebenbürgischen Trachyt-Gebirgen." Jahrb. k. k. geol. Reichsanstalt. Wien. 1861, xi, 153, et seq.

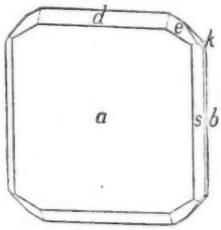
Considering the Fe_2O_3 as the opaque coating of alteration, and the insoluble SiO_2 as the adhering quartz, the composition of the unaltered mineral will be:

			Oxygen ratio.	
SiO_2	25·61	32·41	17·275	1·12
FeO	51·75	65·49	14·539	1·00
MgO	1·66	2·10	·840	
	79·02	100·00		

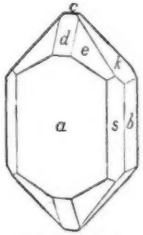
which is essentially the composition of the unisilicate fayalite.

Perfectly fresh, unaltered crystals about a millimeter long were subsequently found in small lithophyses in compact obsidian from half a mile north of Lake of the Woods. A very careful qualitative test showed that the crystals were an iron silicate containing no magnesia. They are in thin, square or rectangular plates, of a light honey-yellow color, perfectly transparent and free from inclusions of other minerals, but occasionally containing gas cavities. They show very slight pleochroism, pale greenish yellow parallel to the *b* axis and golden yellow parallel to the *c* axis. The cleavage parallel to the brachypinacoid is good, but a second at right angles to the first is less distinct and is probably in the plane of the macropinacoid as in olivine.

1.



2.



Mr. S. L. Penfield, of the Sheffield Scientific School, has kindly determined and figured the crystallographic forms presented by the rectangular, tabular crystals from the locality north of the Lake of the Woods, and the more elongated and pointed crystals, from Obsidian Cliff. The measurements were made on a thin tabular crystal 0·1^{mm} thick and 0·8^{mm} broad, which was broken across the prismatic zone. The observed forms were *a* (100, $i\text{-}\bar{i}$), *b* (010, $i\text{-}\check{i}$), *s* (120, $i\text{-}\breve{2}$), *e* (111, 1), *d* (101, 1-$\bar{i}$), *k* (021, 2-$\check{i}$). Arrangement of planes quite constant as in figure 1. For fundamental angles the two best reflections were chosen.

$$a \wedge s,\ 100 \wedge 120 = 42° 31'$$
$$d \wedge d,\ 101 \wedge \bar{1}01 = 103° 17'$$

giving $\dot{a} : \check{b} : \dot{c} = 0{\cdot}4584 : 1 : 0{\cdot}5791$

The angles measured and calculated were:

		Measured.	Calculated.
$a \wedge b$	$100 \wedge 010$	90°	90°
$s \wedge s$	$120 \wedge \bar{1}20$	95° 8′	94° 58′
$a \wedge d$	$100 \wedge 101$	38° 20′	38° 22′
$d \wedge e$	$101 \wedge 111$	19° 52′	19° 46′
$e \wedge e$	$111 \wedge \bar{1}11$	95° 5′	95° 6′
$a \wedge e$	$100 \wedge 111$	42° 25′	42° 27′
$b \wedge k$	$010 \wedge 021$	40° 45′	40° 49′

The plane of the optical axes is parallel to the base, one of the bisectrices being normal to the macropinacoid as shown by a polarizing microscope. Owing to the minuteness of the crystal examined the divergence of the optical axes was not determined.

The opaque crystals from Obsidian Cliff show the same forms with the additional basal plane, *c*, but are mostly developed as in figure 2. With the exception of the macropinacoid the faces were too dull to give good reflections, and the forms were identified by approximate measurements only.

Similar crystals of fayalite are found in the lithophyses in rhyolite from several localities within the Yellowstone National Park, which will be fully described in the geological report on the survey of that region now in progress under the charge of Mr. Arnold Hague.

These brief notes are published at this time for the reason that well-developed, natural crystals of fayalite have not been found before, so far as we know, though they frequently occur as furnace products and in iron slags. Their natural occurrence in this instance bears a striking similarity to the artificial, the obsidian being as perfect a slag as any artifically produced, and the association of tridymite and prismatic quartz with the fayalite in the closed cavities of lithophyses leaving little doubt as to their igneo-aqueous origin.

Art. X.—*The Genealogy and the Age of the Species in the Southern Old-tertiary;* by Otto Meyer, Ph.D.

Part II.*

The Age of the Vicksburg and Jackson Beds.

The table, given in Part I, indicates that the Jacksonian stands between the Claibornian and the Vicksburgian, but it affords no evidence as to which is the most recent formation: this requires a special discussion.

The history of the age of the Vicksburg bed is closely connected with the literature of the orbitoidic limestone in the vicinity of Claiborne, as the following review shows.

*Errata in table of Part. I.—Nos. 3 and 13. Transpose names under Claiborne and Jackson. No. 17. Substitute *Lea* for *Mr.* after *Astarte sulcata*. No. 80. For *protracta* read *protractus*. Add No. 85 under Jackson and Claiborne *Terebra costata* Lea.

1833. When Conrad was in Claiborne he found in a stratum *lower* than the "Claibornian" a specimen of *Spondylus dumosus* (*Plagiostoma dumosum*). See "Fossil shells of the Tertiary formation," second edition, p. 34.

1834. "Observations on the Tertiary and more recent formations of a portion of the Southern States," by Conrad, Jour. Acad. Philad., vol. vii, pp. 116–157, read April 15, 1834.

Here Conrad mentions the limestone with *Nummulites Mantelli* Morton in the vicinity of Claiborne. As this limestone contains *Plagiostoma dumosum*, in abundance, he considers the stratum at the base of the Claiborne bluff as the upper part of this nummulitic limestone. Thus, he concludes, that the nummulitic limestone *underlies* the Tertiary formation of Claiborne and is Cretaceous.

March, 1846. The second number of vol. i, 2d series of this Journal (1846), contains the following two essays:

1. Conrad, "Observations on the Eocene formation of the United States, etc.," pp. 209–221. Here Conrad says that he no longer considered the nummulitic limestone of Alabama and Mississippi as a connecting link between the Secondary and Tertiary strata, but as Eocene. "Between Claiborne and St. Stephens it forms hills of considerable elevation and abounds in that fine fossil, *Plagiostoma dumosum*. At St. Stephens this limestone constitutes an elevated bluff and abounds in *Nummulites Mantelli*, *Plagiostoma dumosum*, *Ostrea cretacea*, etc. At Vicksburg the *Pecten Poulsoni* is common to this rock and to the Eocene sand." These words are important. Here the Vicksburg is mentioned the first time, and at the same time parallelized with the nummulitic limestone of Alabama.

2. As postscript to this number of the Journal, pp. 313–315, there is a letter from Charles Lyell, dated Claiborne, Ala., Feb. 4th. In this letter Lyell speaks on several subjects and says, of the nummulitic limestone, that it had been referred to a pre-Tertiary age, but he considered it even younger than the Claibornian, for it occurs on higher places than the Claiborne bluff, "a circumstance which, in a region where the stratification is horizontal, would imply a newer deposit. . . . I did not meet with the limestone in question in the bluff at Claiborne, which, I have no doubt, is owing to the fact that the calcareous strata are cut off at the top before they extend upward into the nummulitic beds."

We see, that Lyell does not show, why Conrad's opinion, based upon *Spondylus dumosus*, is wrong, but he states, in a few words, that the nummulitic limestone overlies the Claiborne strata. His reasons are: that the stratification is horizontal, and the nummulitic limestone occurs higher than the Claiborne

bluff. If one of these two suppositions had been proved and the other was doubtful, there would be no right to draw the conclusion of Lyell, even if it had been proved besides that there are no faults. But Lyell proves none of them. As for the stratification, he was unable to bring forward any other fact, than that he did not notice any dip at the points where he made his observations. In a diagram, in his essay of the next year, he represents a dip, not as he observed it, but as he needs it for his hypothesis. As to the relative height, he also does not bring forward any proof; and I cannot imagine how he could possibly have obtained in Claiborne at that time any reliable data about it. In short, Lyell's new hypothesis was without any proof at all, and was in contradiction to an observed fact. Moreover, to sustain it, he had to make another hypothesis, also entirely without proof: that this limestone was totally eroded in Claiborne, but preserved in the vicinity.

May, 1846. Charles Lyell, "On the newer deposits of the Southern States of North America" (Quart. Jour. Geol. Soc. London, ii, pp. 405–410, read May 6, 1846). On this question Lyell writes, p. 408: "After visiting Claiborne and the country on the other side of the Alabama River in the fork of that river and the Tombecbee, I am persuaded that the nummulite limestone is Eocene, newer than all the beds of the well known Claiborne bluff. It is in fact more modern than the sandy deposit, from which the Eocene shells described in the publications of Messrs. Conrad and Lea were derived." We have here a more decidedly pronounced expression of his hypothesis without any proof.

July, 1846. Conrad, "Tertiary of Warren County, Miss." (this Journal, ii, 2d series, pp. 124, 125). Here Conrad briefly announces that he collected 103 species of fossils at Vicksburg; he enumerates the genera, but had not yet made descriptions of the species. To what age are these fossils attributed? He himself had parallelized this Vicksburg bed with the nummulite limestone of Alabama. Sir Charles Lyell claimed this limestone to be more recent than the Eocene of Claiborne. So, if Conrad did not wish to oppose this opinion of Lyell, he had only the choice of considering these Vicksburg fossils more recent than those from Claiborne. The fossils, considered alone, did not show their age, and Conrad seems not to have made even an attempt to question the decidedly pronounced opinion of the celebrated English geologist; for in this first announcement of the Vicksburg fossils we see distinctly the presupposition of their newer age, and he considers only whether they are more nearly related to the Miocene or to the Eocene. He says: "The Vicksburg group has decidedly more affinity with the Eocene group than with that of the Miocene, for there is only

one species that closely resembles a Miocene fossil. The limestone of Clark County, Ala., and of St. Stephens contains *Nummulites crustaloides* and *Pecten Poulsoni* Morton, two fossils which abound* in the Vicksburg deposits, and this limestone is, therefore, *probably* of the same age as the Tertiary beds of Vicksburg. This formation marks a distinct era in the American Tertiary system, intermediate between the Eocene and Miocene formations, but more nearly allied to the former, etc."

In this way the age of the Vicksburg fossils was determined, and what Conrad says afterward about it is only the following out in detail of this once accepted supposition.

Sept., 1846. Conrad, "Eocene formation of the Walnut Hills, Miss." (this Journal, ii, 2d series, pp. 210–215). Conrad, speaking of the Vicksburg locality, says, p. 210: "One of the most abundant bivalves is *Pecten Poulsoni* Morton, a species occurring in the white limestone near Claiborne, Ala. A very thin wafer-shaped nummulite, described by Dr. Morton, is common in the limestone as well as in the strata above, and connects the formation of Vicksburg with the Eocene white limestone of St. Stephens." Here Conrad omits the word "probably," which he used in the preceding essay, and from this time the identity of the Vicksburg beds and the nummulite limestone in Alabama is an accepted fact in American literature. Though I consider this identity probable, it cannot be said to be proved.

June, 1847. Lyell, "On the relative age and position of the so-called limestone of Alabama" (Quart. Jour. Geol. Soc. London, iv, pp. 10–16, read June 9, 1847. Published also with a few alterations in this Journal, iv, 2d series, pp. 186–191, Sept., 1847.

Lyell says about this limestone, referring to his letter of the preceding year: "It was stated to be newer than all the beds of the well known Claiborne Bluff." Then he tries to prove this stated opinion by claiming that the Claibornian bed occurs also at the base of the St. Stephens bluff below the nummulitic limestone. The fossils which he cites from this bed, p. 15, are: "*Terebra costata* Con., *Cardita parva*, *Dentalium thalloides*, *Flabellum cuneiforme* Lonsd., *Scutella Lyelli* Conr., and several more." From the few species which Lyell selects to prove the Claibornian character of the beds, he cites, on the same page, *Dentalium thalloides* and *Terebra costata* as occurring in the Vicksburg bed, and *Flabellum cuneiforme* in the Jackson. So he

* As this is of some importance, and as it is repeated afterward, I have to object here to the word "abound" in relation to *Orbitoides Mantelli* in the sand of Vicksburg. It may be said to be "common," but is not at all "abundant," and is rarer than several other species.

might just as well have deduced a Vicksburgian or Jacksonian age, but he had to corroborate his stated opinion.

1850. M. Tuomey, "First biennial report of the geology of Alabama," Tuscaloosa, 1850. This report contains some interesting sentences, which show that the authority of Lyell must have been very great. Tuomey says, p. 149: "Sir Charles Lyell has proved that the white limestone is newer than the fossiliferous bed at Claiborne by showing that this bed, which contains identical fossils, underlies the bluff at St. Stephens. This is certainly the case, for although this bed is not seen at the base of the bluff, it is overlaid, as I have just stated, by a yellow limestone, which is a prolongation of that at St. Stephens."

The following is of special interest, pp. 156, 157: ". . . Mr. Conrad . . . referred the whole to the upper part of the Cretaceous system, supposing, as I have said in another place, that the Claiborne bed was newer, instead of being, as we now know it, older than the white limestone.

"It is curious to observe, after the difficulties have been cleared away that surround pioneer explorations of every description, how obvious everything appears and how difficult it is to account for the mistakes of our predecessors. But in the present instance it must be recollected that the Claiborne fossiliferous bed is nowhere in absolute juxtaposition with the overlying Orbitoides limestone, and even at St. Stephens I was unable to detect it at the base of the bluff, although I examined it at an unusually low state of the water. Nevertheless, the position of the bed above the bluff, together with its dip, leaves no doubt of its sinking below the white limestone."

The reason why Tuomey could not detect this bed at the base of St. Stephens bluff is very simple and was even known to himself, as will be seen by the juxtaposition of the following two sentences. Lyell says in his essay, p. 15: "The water of the river at the time of my visit was too high to enable me to collect fossils from the beds at the base of the cliff, but I was afterward furnished with them through the kindness of Professor Brumby of Tuscaloosa." Tuomey says, p. 158: "This is the bed described in the preceding pages as extending from Baker's Bluff to a point about half a mile above St. Stephens; and it was from this bed the fossils were taken which were sent by Professor Brumby to Sir Charles Lyell."

So we see that Lyell's Claibornian bed at the base of St. Stephens Bluff not only according to his own determinations need *not* be Claibornian, but that it is also *not* at the base of St. Stephens Bluff.

From this time, however, the higher position of the Orbito-

idic limestone and the newer age of the Vicksburg fossils was considered a proved fact in the literature. As the Claibornian was considered Middle Eocene, Conrad called the Vicksburg bed "Newer Eocene." Afterward it appeared to him more proper to use the name of "Upper Eocene" for the intervening Jackson bed, and thus finally the Vicksburg fauna received the name of Oligocene.

1860. Interesting as it would be, I cannot review here the whole literature regarding this subject,* but it is necessary to criticize this point at least briefly, as it is presented in Hilgard's Geology of Mississippi (Jackson, 1860). Only a competent and careful examination of the fossils could indicate the relation of the Old-tertiary strata in Mississippi; but Hilgard seems to have studied this Tertiary paleontology very little, and when it was necessary to prepare a list of fossils he transferred the work to Professor W. D. Moore. The division: Claiborne, Jackson and, at the top, Vicksburg was accepted as a proved fact, as well as the identity in age of the Vicksburg and St. Stephens beds. On this basis he undertook to map the marine Old-tertiary. He found *Orbitoides* and *Pecten Poulsoni* in the east (Wayne County), in the west (Vicksburg), and besides in Rankin County. So he connected these localities, thus forming a "belt," which pointed admirably toward St. Stephens. But unfortunately this belt would pass right through Jackson, an older formation. Therefore Hilgard made this belt make a sharp curve to the south around Jackson. Then he drew a parallel Jacksonian belt; and farther north he found the Claibornian. All this would admirably agree with the general dip southward. An "irregularity"—the strata from Jackson to Canton indicating a northern dip†—seems not to have troubled him very much. I could not find a place in his work where an overlying of the Jacksonian by the Vicksburgian was shown. It is no wonder that Hilgard worked in this way, if we consider that he had to map an enormous territory without reliable preparatory work, almost without assistance and in so short a time, that he could not even by a glance examine large areas. The only criticism that can be made

* Attention might be called at least to the following sentence of Winchell's, (Proc. Am. Assoc. Adv. Sci., 1856, part II, p. 86: "The thick bed of limestone which underlies the sandy belt at Claiborne [the Claibornian] has not been recognized elsewhere. Perhaps its occurrence here is accidental." We see that Winchell, working on the accepted theory, comes to the conclusion that the stratum of more than fifty feet below the Claibornian may be accidental, as it cannot be found elsewhere.

Winchell determines, p. 85, a bed as Claibornian without citing any fossil to prove this character.

† Lyell represents in a diagram (1847) the dip from Jackson westward.

against him under these circumstances is that he represented suppositions too much like facts.

We find more reason to complain of the work which Professor Angelo Heilprin has published on the Old-tertiary. His first essay is:

1. "On some new Eocene fossils from the Claiborne Marine formation of Alabama."* I leave a determination of most of these "new" species till I have had an opportunity of examining at leisure the type specimens. Some of them, however, can be recognized very easily from the descriptions and figures. *Solarium striato-granulatum* Heilpr. is a specimen of *Solarium ornatum* Lea; *Natica bisulcata* Heilpr., a specimen of *Natica magno-umbilicata* Lea; *Tornatella bicincta* Heilpr. is *Actaeon lineatus* Lea; *Odostomia lævigata* Heilpr. is a fragment of *Actæon melanellus* Lea; *Delphinula solaroides* Heilpr. is either a young specimen of *Solarium elegans* Lea, or an old one in which the larger whorls are broken off.

2. "A comparison of the Eocene Mollusca of the United States and Western Europe, etc."† I have already in a former paper‡ excluded all identifications of Professor Heilprin which were made from figures. A collection of several hundred species of the French Old-tertiary, which I received from Mr. Cossmann in Paris, convinced me that the rest of his comparisons have also little value. In the French Old-tertiary as well as in the American there are quite a number of similar forms (connected by descent?), and only a large amount of material compared by an experienced observer can furnish reliable identifications or other results of comparison.

3. "On some new Lower Eocene Mollusca from Clarke County, Ala., etc."§ Specimens from Wood's Bluff, which I received from Professor E. A. Smith and Mr. Aldrich in Tuscaloosa, convinced me that no reliance can be placed upon these determinations and descriptions. I mentioned in part I of this essay that *Dentalium micro-striatum* Heilpr. has most probably a fissure, although Professor Heilprin says "there being no fissure." Where I have received the corresponding material I have found none of the Claibornian determinations correct. A striking example is the determination "*Corbula rugosa* Lam. (*C. oniscus* Conr. var. *C. gibbosa* Lea)."

The two species in Claiborne, *C. gibbosa* Lea and *C. Murchisoni* Lea (*C. oniscus* Conr.), are two entirely different species; neither of them is identical with the French *C. rugosa* Lam., and neither of the three is identical with the species in Wood's Bluff, which I have had in my collection for some time under

* Proc. Acad. Nat. Sci. Philad., 1879, pp. 211–216.
† Proc. Acad. Nat. Sci. Philad., 1879, pp. 217–225.
‡ Proc. Acad. Nat. Sci. Philad., 1884, p. 104.
§ Proc. Acad. Nat. Sci. Philad., 1880, pp. 364–375.

the name of *Corbula Aldrichi*, n. sp. It has radiating striæ on the umbonial part of the surface, a characteristic which I had not seen before in a Corbula.

4. "Contributions to the Tertiary Geology and Paleontology of the United States."* As the author is curator of the collection of the Philadelphia Academy, where so many type specimens of Tertiary invertebrates are said to be, I had looked with eagerness for this work, announced a long time since,† hoping to receive much information concerning many doubtful points, especially in connection with Conrad's descriptions. But I found that a study of the paleontology of the Southern States had not been attempted in it. The book contains nothing but reprints of previous essays of the author, increased by a "succinct statement of the Tertiary geology of each of the several States," and a map. How did Professor Heilprin map the Southern Old-tertiary? E. A. Smith has given a map of Florida,‡ where he carefully makes a distinction between the few localities where limestone with Orbitoides has been observed and the large area where this limestone is supposed to exist; all this is colored Oligocene by Professor Heilprin. The risk of mapping in this way can perhaps be fully appreciated only by one who has, like myself, tried to get a clear opinion of the Oligocene formation by studying for years its typical localities in Europe. Further, Professor Heilprin traces the Oligocene (p. 3 and p. 4), connecting link after link, from the Mississippi River through Florida, Jamaica, Antigua, Trinidad and St. Bartholomew, to the Vicenza deposits in Italy and the Mayence Basin in Germany, and ends this speculation by the words (p. 4): "we thus have the parallelism established between our Vicksburg or Orbitoidic bed and those of the typical Oligocene of Southern Europe." Having in my possession more than four hundred species, which I collected myself at both ends of Professor Heilprin's long chain, in the Mayence Basin and at Vicksburg, I ought to have found at least some identical forms, but as yet I have not noticed a single one. Considering the difficulty of determining the relative age of two localities only, such as Vicksburg and Jackson, which are situated near each other and contain hundreds of well preserved fossils,§ we may ask, what guided Professor Heilprin through thousands of miles? The answer is, the Foraminifera Orbitoides. It is scarcely necessary to repeat, what

* By A. Heilprin, Philadelphia, 1884, published by the author.

† C. A. White wrote 1880 (Am. Naturalist, p. 255): "Mr. Heilprin has begun the preparation of a monograph of the Tertiary fossils of Eastern North America."

‡ This Journal, III, vol. xxi, 1881, p 305.

§ Conrad described 34 species from Jackson; I collected there about 150. Having received during the printing of this article additional material from this locality, I think that this number must be increased, perhaps considerably.

is generally known, that Foraminifera of the most different formations often look extremely similar, and that the genus Orbitoides cannot be considered at all a "Leitfossil" for any certain Tertiary formation. But it may be of interest to quote what has been published about this same American Orbitoides. Lyell sent it to E. Forbes and A. d'Orbigny. Forbes writes to him,* June 14, 1847: "As the subject stands at present, then, we have no right to infer from the presence of an Orbitolite, however abundant, that the stratum in which it occurs belongs to one period more than another between the commencement of the Cretaceous epoch and our times." D'Orbigny writes, ibid., June 18, 1847: ". . . It is, in fact, of all genera, that perhaps which has been most often misunderstood, and I should call it the greatest culprit in geology, . . . the Orbitoides are found in the Cretaceous and Tertiary formations."

The gap between Mississippi and Florida, without the necessary data for a mapping, is filled by Professor Heilprin by prolonging the hypothetical belts of Hilgard through the States of Alabama and Georgia, till they meet the bulk of the Oligocene of Florida. My studies lead me to saying, that I consider Professor Heilprin's map, as far as the divisions of the Southern Old-tertiary is concerned, entirely imaginary.

Mr. Heilprin has not made himself a single observation in the Southern Old-tertiary formation, but is acquainted with its geology only by a somewhat superficial knowledge of a literature which needs much criticism. For this reason I do not wish to give any further criticism of the text, but we may see at least his views about that limestone, which interested us in the preceding pages. We find, p. 29:

"4. 'White limestone' (Jacksonian), best exhibited at Claiborne (upper portion of bluff) and St. Stephens (lower moiety of bluff), not very abundant in fossils—*Pecten membranosus*, *P. Poulsoni*, *Ostrea panda*, *Spondylus dumosus*, '*Scutella*' *Lyelli*, etc. —50—? feet."

While Lyell in the year 1846 had to confess that he could not find this white limestone in the upper portion of the bluff, and concluded that it must have been eroded, this upper portion of the bluff, according to Professor Heilprin, has become in 1884 typical for this limestone and best exhibits its characteristic features. The specimen of *Spondylus dumosus*, which Conrad found in 1833 in the lowest strata, must have migrated upward since that time, and the other species must have come from other places. They are indeed "not very abundant," for I could not find a single specimen.

Having now shown how the age of the Vicksburg and the Jackson beds was determined, I give in the following pages

* Quart. Journ. Geol. Soc. London, iv, p. 12.

observations of my own, which make it very probable to me that Vicksburg is the *most recent* bed.

1. *Profile of the bluff at Claiborne, Ala.*—This famous bluff has been described by Lea, Conrad, Lyell, Hale, Tuomey and Mell,* and yet none of the given profiles represents the facts correctly, at least at that point, where I observed. At a little distance above the "upper landing" there is a vertical exposure of the bluff of more than a hundred feet, showing the different strata so distinctly that the whole profile might be photographed. I was told by inhabitants of Claiborne that this exposure was caused by a landslide some years ago.† By a simple and yet reliable method (a string with a weight attached) I measured the thickness of the strata on one vertical line and then examined their characters, wherever they could be reached. The water at the time of my visit was so high that I could not determine the thickness of the stratum *b*, and moreover could not examine the stratum below it, which according to Conrad and Tuomey is only visible at very low water and contains fossils, the careful examination of which must be of importance.

The profile at the mentioned point is the following:

k.	Diluvium? red loam and pebbles.	
i.	Mostly limestone.	33 feet.
h.	Glauconitic sands and clays.	11 feet.
g.	Gray sandy stratum with fossils.	6½ feet.
f.	Red sand, fossils badly preserved, similar to *e*, but *Scutella* very common.	3 feet.
e.	Highest Claibornian. Ferruginous sand with the Claibornian fossils. Lowest Claibornian.	17 feet.
d.	Color a bluish gray.	26 feet.
c.	Mostly limestone with large ferruginous concretions.	8 feet.
b.	Calcareous limestone with green sand, *Ostrea*, *Pecten*, *Scalpellum*, *Scutella*.	30? feet.

In the lower limestone *b* I collected the following fossils: Casts of shells; teeth of sharks and rays; an otolite of a fish: *Endopachys Macluri* Lea sp., in bad condition; a fragment of a *Scalaria*; a specimen of an *Orbitoid*; a specimen of *Venericardia parva* Lea, showing more the typical form of the Claibornian specimens than that of the var. *Jacksonensis*. More frequent and in better condition are the following species:

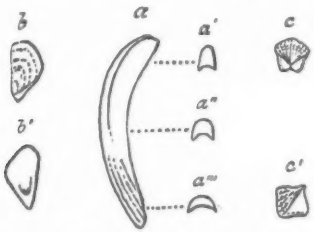
Ostrea sellæformis Conr., *O. Alabamiensis* Lea, *Pecten Deshaysi* Lea (includ. *P. Lyelli* Lea), *P. scintillatus* Conr., "*Scutella*" *Lyelli* Conr., *Scalpellum Eocenense*, n. sp.

* "The Claiborne group and its remarkable fossils," by T. H. Mell, Jr.—Trans. Am. Instit. of Min. Engin., 1880.

† Thus the Alabama River seems to be cutting its bed deeper. I observed a similar undermining of its banks in Moody's Branch near Jackson, Miss., and other creeks seem to do the same. This part of the American coast has risen more or less gradually during all the later formations, and the mentioned phenomenon may, perhaps, indicate that it is rising still at the present time.

Besides the figured piece *b*, I found valves of the same form but larger. The umbo of the carina is placed at the apex. As far as I know the literature, this is the first Lepadite from the American Tertiary.

The top of stratum *b* is formed by an oyster bank. In stratum *c* I did not find a trace of a fossil, and in *d*, *h* and *i* no determinable fossil. In *e* there must be made a distinction between the highest part and the lowest part of it, "*Highest Claibornian*" and "*Lowest Claibornian*," as there is a paleontological difference which, though not striking, cannot be neglected. I found in the stratum *e* also a specimen of an Orbitoid. The fossils in stratum *g* are very fragile. Larger specimens could be obtained only in poor fragments, and even



a. Carina of *Scalpellum Eocenense*, n. sp.
a', *a''*, *a'''*, vertical sections of this carina.
b and *c*, lateralia of the same species?, different views.

the smallest could be obtained only with difficulty. The most common of them seems to be *Alveinus minutus* Conr., which is apparently one of the most characteristic fossils of the Southern Old-tertiary. A specimen of *Venericardia parva* Lea shows no approach to the Jackson angular form, and is as rounded as the most rounded Claibornian specimens. A young specimen of *Corbula Murchisoni* Lea shows the sharp carina of the Clabornian form.

2. *Profile at Enterprise, Miss.*—The profile given by Hilgard* is not correct. The Chickasawhay River near Enterprise seems to be little fitted to furnish a reliable profile. Each of the creeks on the west side, however, shows distinctly *two* fossil-bearing strata. The upper one contains quite a number of species, but they are badly preserved. They have a Claibornian character (for instance, *Venericardia rotunda* Lea) and are apparently not the species which Conrad received from Enterprise,† which I could not find. The lower stratum is an indurated sand with glauconite; and, besides shark teeth, I found nothing else in it except

* Geol. of Miss., p. 125.

† Am. Jour. Conch., 1865, p. 137.

Ostrea sellæformis Conr., *O. Alabamiensis* Lea, *Pecten Deshaysi* Lea (incl. *P. Lyelli* Lea), *P. scintillatus* Conr., "*Scutella*" *Lyelli* Conr., *Scalpellum Eocenense* Meyer.

These are exactly the same species as in the stratum *b* of Claiborne, and the bed in Enterprise is therefore evidently a *facies* of this stratum.

3. *Profile at Vicksburg, Miss.*—Directly in front of the national cemetery near Vicksburg there is a creek (bayou) forming a waterfall, at which the following facts can be observed: At the top there is a stratum with the "Vicksburgian" fossils; below this follows a stratum of limestone with *Pecten*, about thirty feet thick; at the base is a clayey stratum with fossils, which must be strictly separated from the upper ones. These strata may be called "Higher," "Middle" and "Lower Vicksburgian." The Higher Vicksburgian contains the fossils, generally known as Vicksburg fossils. The Lower Vicksburgian is characterized at first sight by the absence of *Arca Mississippiensis* Conr., which is abundant in the Higher Vicksburgian. It is very interesting as containing a species of *Cœcum* and two species of the Pteropod *Styliola*, two genera hitherto unknown in the American Old-tertiary.* Though I have not found as yet the species mentioned by Conrad, the Lower Vicksburgian is apparently identical with that stratum, which Conrad called Shell Bluff group,† in Vicksburg; but, if so, this name cannot be used for the Vicksburg stratum, because it implies a parallelism with Shell Bluff, which is as yet entirely without any proof.

After the description of the three preceding profiles, the following reasons for indicating as the true succession—Vicksburg, Jackson and Claiborne, with Claiborne at the top, may be mentioned:

1. The Orbitoidic limestone, parallelized by Conrad with Vicksburg, is characterized by *Spondylus dumosus* and *Orbitoides Mantelli*. As Conrad found a specimen of *Spondylus dumosus* in the lower limestone of the Claiborne bluff, he concluded that this lower limestone formed the top of the Orbitoidic limestone. Lyell, upon whose authority the contrary opinion was accepted, could adduce no facts at all against Conrad's theory, and this theory is made more probable by my finding a specimen of the second characteristic fossil, an Orbitoid, in this lower limestone.

2. If the stratum *b*, which occurs about a hundred feet below the surface in Claiborne, appears near the surface in Enterprise, a dip of the strata is indicated, which makes it probable that we find older beds as we go in the northwestern direction.

* Two other species of *Styliola* occur in Jackson.

† This Journal, 2d series, i, 1866, p. 96.

3. If the Jacksonian were younger than the Claibornian, the Highest Claibornian ought to be more nearly related to it than the Lowest. I found, on the contrary, the fauna of the latter more similar to the Jacksonian. For instance, *Lunulites interstitia* Lea is common in Jackson, not rare in the Lowest Claibornian, very rare in the Highest. *Mitra pactilis* var. *dumosa* is common in Jackson; *M. pactilis* is rarer in the Lowest Claibornian, and apparently absent in the Highest.

4. If Jackson were older than Vicksburg, the Lower Vicksburgian ought to show more relationship to it than the Higher. I found rather the contrary; for instance, *Astarte parva* Lea, in the lowest stratum, is more different from the Jackson form than in the highest stratum.

5. As a proof of this succession and derivation, the following facts are to be considered: *Venericardia rotunda* Lea in its young form resembles the allied Jacksonian species. *Fulgur filius* Meyer repeats in its sculpture *Fulgur Mississippiensis* Conr. *Tellina Vicksburgensis* Conr. resembles the young form of the allied variety in Jackson (see part I, Nos. 22, 69, 35).

6. Among the fossils from Wood's Bluff, Ala., which I received, there is a Vicksburgian species (*Pleurotoma terebralis* Lam. var. *carinata* Conr.), a Jacksonian species (*Actæon*, sp.), but no characteristic Claibornian species. According to the determinations of Professor Heilprin, moreover, *Natica Mississippiensis* Conr. and *Pecten Poulsoni* Mort. occur in these strata, so that they show a decidedly Vicksburgian character. According to Professor E. A. Smith they are stratigraphically far *below* the Clabornian.

7. In Harper's Geology of Mississippi (Jackson, 1857, p. 141), a bluff in Wayne County is described and extensively figured. Harper's stratum on the top *b*, "containing Pectens of several species, Gallerites and several Ostreæ," is apparently my stratum *b* from Claiborne, which I showed to occur near the surface at Enterprise, a place not very distant from this locality. Harper's second stratum below, called *d*, "filled with *Orbitoides*, *Ostrea*, *Pecten* of several species, *Arca*, *Flabellum*, *Cardita*, *Gallerites*, etc.," seems to be of Jacksonian or Vicksburgian character.

ART. XI.—*On the probable occurrence of the Great Welsh Paradoxides*, P. Davidis, *in America;* by GEO. F. MATTHEW.

THIS, the largest and most remarkable species of Paradoxides occurring in the Primordial fauna of Europe, has not, so far as the writer is aware, been hitherto found in America. It

was discovered by Dr. Henry Hicks near St. Davids in Wales about twenty years ago, and was subsequently found (by Professor O. Torell?) in Sweden in 1869.

Through the kindness of Mr. J. P. Howley, Director of the Geological Survey of Newfoundland, the writer received, a few months ago a box of Cambrian fossils from that Island and among them fragments which appear to belong to this species. Its most important characters are well represented by the posterior half of the center piece of the buckler, by the free cheeks, the long cylindrical genal spines and the peculiar hypostome. The outlines and aspect of the parts preserved agree exactly with those of specimens from the Swedish beds figured by G. Linnarsson.* The Newfoundland fossil sent me is not *P. Bennetti* of Salter, nor is it Green's *P. Harlani;* from both it is distinct by the outlines and furrows of the glabella, by the short eyelobe and by the great extension of the facial suture behind the eyelobes.

A large species of Paradoxides is also found in the Cambrian slates at Saint John, New Brunswick, but the fragments recovered are not sufficiently large or perfect to make it clear that it is the species above referred to. This crustacean of the Saint John Group was nearly a foot and a half long (supposing it to have had extended spines next the pygidium like *P. Davidis*).

The American examples of *P. Davidis* occur in a hard black silico-calcareous shale at Highland's Cove, Trinity Bay, Newfoundland, in company with species of Agnostus—*A. punctuosus* Ang., *A. lævigatus* Dalm., *A. Acadicus* Hartt (var. *declivis* mihi.) These fossils indicate a new horizon in the Paradoxides beds of America somewhat above that of Braintree, or the known horizons of Newfoundland and New Brunswick.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a simplified method of liquefying Oxygen.*—It is well known that liquid ethylene, boiling in free air, gives a cold sufficient to liquefy oxygen under pressure, only when the latter is suddenly expanded. By evaporating the ethylene in vacuo or by using liquid methane in free air, Cailletet produced the temperature of liquefaction, both of oxygen and nitrogen. Since, however, ethylene is more readily procurable in the liquid form than methane, the author has experimented on the use of this substance evaporated in free air and has succeeded in obtaining by its means a temperature sufficiently low to liquefy oxygen completely. This he effects by hastening the evaporation of the ethylene sim-

* De Undre Paradoxideslagren, Stockholm, 1883, Plate II.

ply by passing through it a current of air or of hydrogen previously cooled to a low temperature by the agency of methyl chloride. The steel cylinder containing the liquid ethylene is supported vertically with its orifice downward. To this a copper worm, 3 or 4 millimeters in diameter, is attached, and is closed at its lower end by a screw plug. On cooling this worm to $-70°$ by means of methyl chloride, the ethylene contained in it has at this temperature only a feeble tension, and flows out when the screw plug is opened, without much loss. The liquid ethylene is received in a test tube of thin glass placed within a larger glass vessel containing dry air. It is necessary now only to accelerate its evaporation by passing through it a rapid current of the cooled air or hydrogen, in order to see oxygen compressed in a glass tube immersed in the ethylene, condense into a clear colorless liquid having a sharply defined meniscus. By means of the hydrogen thermometer, the temperature which was thus obtained with ethylene was measured and found to be $-123°$; a temperature below the critical point for oxygen. In this form the experiment is one well suited to the lecture table.—*C. R.*, c, 1033, April, 1885. G. F. B.

2. *On the preparation of Cyanogen in the wet way.*—While studying to learn the best conditions for the preparation of Bong purple, JACQUEMIN mixed a concentrated solution of copper sulphate with one of potassium cyanide and immediately obtained a tumultuous evolution of cyanogen gas, while the temperature of the liquid rose 40°. Although this fact had been already observed, the author has succeeded by a simple modification of the experiment, in making the reaction complete so as to obtain in the free state all the cyanogen of the cyanide. A solution of two parts copper sulphate in four of water is placed in a flask on the water bath, and by means of a funnel furnished with a stopcock, a concentrated solution containing one part of pure potassium cyanide is allowed to enter. The reaction begins actively even at the ordinary temperature, and when this diminishes, the temperature of the water bath is raised. In one experiment ten grams pure potassium cyanide gave 850 c. c. of pure cyanogen. If commercial cyanide be used carbon dioxide gas is obtained in addition. In the reaction, cupric cyanide is at first formed. This being unstable separates into cuprous cyanide and cyanogen. Two processes have been devised by the author for obtaining the cyanogen from the cuprous cyanide. On standing, the cuprous cyanide settles to the bottom of the flask and the supernatant liquid is decanted. In the first process, a slight excess of a 30° solution of ferric chloride is poured into the flask. The action begins even in the cold and an abundant evolution of cyanogen takes place on slightly warming the liquid. The ferric chloride is reduced to ferrous chloride the excess of chlorine uniting with the copper of the cuprous cyanide, producing cuprous chloride and setting the cyanogen free. By the further action of the ferric chloride the cuprous chloride is converted into cupric chloride. The second process consists in adding to the washed cuprous

cyanide, manganese dioxide and acetic acid, and slightly warming the mixture. Acetates of copper and of manganese are formed and the cyanogen is evolved. When the operation is terminated, the addition of sulphuric acid enables the acetic acid to be distilled off for a new operation. In separating the cyanogen which is evolved, from any other gaseous substances with which it may be mixed, Jacqueminfinds that this gas is very readily absorbed by aniline to form cyaniline, and hence recommends this substance as the best with which to absorb it, since neither CO_2, CO, nor air are appreciably absorbed by aniline.—*C. R.*, c, 1005, 1006, April, 1885. G. F. B.

3. *On two new Alkalimetric Indicators.*—Ville and Engel have proposed two new indicators for alkalimetry, both of which are unaffected by carbonates; so that by means of these, the free bases may be determined volumetrically in presence of the alkali carbonates. The first of these is sulphindigotic acid. It is prepared by neutralizing with calcium carbonate the ordinary solution of indigo in fuming sulphuric acid, diluting with ten parts of water and filtering. While carbonates are without action upon the blue color of this liquid, caustic alkalies change it to yellow. In titering with it, a few drops of this blue liquid are added to the solution containing the caustic alkali, which turns it yellow. As soon as the neutralization is complete, the color of the liquid changes back to blue, passing through an intermediate green. By placing the beaker on a white paper each drop of acid as it enters produces a blue spot at the point of contact, which ceases on neutralization. The second substance proposed as an indicator is the soluble blue C. 4. B. of Poirier. This in solution in water (2 parts in 1000) is even more sensitive than the sulphindigotic acid. In presence of alkali carbonates this solution remains blue but becomes red under the influence of the free bases. If to a solution containing both carbonates and free bases, a few drops be added, a rose-red liquid is obtained in which each drop of the graduated sulphuric acid, as it enters, produces a blue color, which so long as neutralization is incomplete is transient, but which as neutralization is approached passes through violet into a permanent blue when no more caustic alkali is present. With these indicators, the determination of free alkali in presence of carbonated, is rendered as rapid and accurate as is ordinary alkalimetry with litmus or orange No. 3.—*C. R.*, c, 1073, April 1885. G. F. B.

4. *On the Separation of Nickel and Cobalt.*—Ilinski and v. Knorre have proposed a new method of separating nickel and cobalt founded on the properties of the compounds which these metals form with nitroso-β-naphthol. If to a neutral aqueous solution of sodium-nitroso-β-naphthol an excess of a cobalt salt be added in solution, a brownish red precipitate of cobalto-nitroso-β-naphthol $[C_{10}H_6O(NO)]_2Co$ is produced which is very sparingly soluble in water. By digestion with potassium hydrate, this precipitate loses slowly, by warming with acids rapidly, a portion of

its cobalt and is converted into cobalti-nitroso-β-naphthol, $[C_{10}H_6O(NO)]_3Co$, of a purple-red color. The same body is obtained when a neutral or acid solution of a cobalt salt is added to a solution of nitroso-β-naphthol in alcohol or acetic acid. It is remarkably stable, resisting acids, alkalies, oxidation and reduction reagents, etc., to a marked degree. It dissolves in fuming nitric acid and in strong sulphuric acid, but is precipitated unchanged on dilution. Boiled with strong alkalies, it is only slowly attacked. Hot acetic acid (50 per cent) dissolves it sparingly, but deposits it again completely on cooling. It is slightly soluble in strong alcohol, more so in dilute alcohol and readily in aniline and phenol. Nickel salts give under similar circumstances nickel-nitroso-β-naphthol as a brown-yellow precipitate difficultly soluble in water and alcohol and from which hydrochloric and sulphuric acids easily remove the nickel leaving the nitroso-β-naphthol, which in presence of sufficient acetic acid goes into solution. As therefore a nickel salt produces no precipitate in an acetic solution of nitroso-β-naphthol containing hydrogen chloride, the authors recommend the following method of separation: To the solution containing the nickel and cobalt as sulphates or chlorides, acidulated with hydrochloric acid and slightly warmed, a hot solution of nitroso-β-naphthol in 50 per cent acetic acid is added. The precipitate is allowed to deposit and the supernatant liquid tested with more of the reagent. After some hours, the precipitate is filtered off, washed first with cold, then with hot water, and then with a 12 per cent solution of hydrochloric acid to remove the whole of the nickel. After drying, a few grains of oxalic acid free from ash are added, and the precipitate is burned as usual in a tared crucible. The residue is ignited in a current of hydrogen gas and weighed as metallic cobalt. The nickel may be determined in the filtrate as usual. By determining both metals in an aliquot part of the solution by precipitation with potassium hydrate and reduction to the metallic state, and then estimating the cobalt in another similar portion as above, the nickel is readily determined by difference. In 20 c.c. of a solution containing 0·0382 gram cobalt, 0·0380, 0·0378, and 0·0379 gram were obtained in three experiments. Fifty c.c. of this cobalt solution, mixed with 100 c.c. of a nickel solution containing 0·2097 m., gave 0·0947 gram Co instead of 0·0955. As to delicacy, 0·2 c.c. of a cobalt solution containing 0·00004 gram Co, mixed with 5 c.c. of a nickel solution containing 0·0105 Ni, gave when mixed with the solution of nitroso-β-naphthol, an immediate turbidity, and after a time flocks of the cobalti-compound separated.—*Ber. Berl. Chem. Ges.*, xviii, 699, March, 1885. G. F. B.

5. *On a ready method of preparing Tartronic acid.*—Although many processes have been devised for preparing tartronic (oxymalonic) acid, yet owing to the cost of the crude material or the very small yield, this acid has been but little studied. PINNER has recently observed the formation of this acid by the action of sodium hydrate upon ethyl trichlorlactate according to the equa-

tion: $CCl_3.CHOH.CO_2C_2H_5+(NaOH)_5=CO_2Na.CHOH.CO_2Na+(NaCl)_3+C_2H_6O+(H_2O)_2$. To prepare it, he adds to a 10 per cent sodium hydrate solution warmed to 60° or 70°, the trichlorlactic ether slowly, in the proportion of one molecule of the latter to 5 of NaOH. After standing a short time, dilute acetic acid is added to weak acid reaction and then barium chloride solution so long as this gives a precipitate. After cooling the precipitate is filtered off and washed. It consists of pure barium tartronate. The yield of the barium salt was about 50 per cent of the ether employed. The trichlorlactic ether is readily formed from its nitrile, chloralcyanhydrin, by passing hydrogen chloride gas through its alcoholic solution, heated on the water bath. And the chloralcyanhydrin is produced by the action of hydrogen cyanide upon chloral hydrate. From 1800 grams chloral hydrate, the author obtained 2100 trichlorlactic ether.—*Ber. Berl. Chem. Ges.*, xviii, 752, March, 1885. G. F. B.

6. *Pocket Book of Mechanics and Engineering*, containing a memorandum of facts and connection of practice and theory, by JOHN W. NYSTROM, C.E. 18th edition, revised and greatly enlarged with original matter. 672 pp. 12mo. Philadelphia, 1885 (J. B. Lippincott & Co.).—From 1854 to 1885 this valuable work —small in size but large in the amount of matter it contains—has gone through eighteen editions and has increased two and a half times in size. It contains a vast number of facts conveniently arranged and covering a wide range of subjects. Personal experience with an earlier edition has shown the writer how useful a companion such a book can be.

II. GEOLOGY AND MINERALOGY.

1. *Coals and Lignites of the Northwest Territory;* by G. CHRISTIAN HOFFMANN, Chem. and Min. Canada Geol. Survey. From the Geol. and Nat. Hist. Survey of Canada. Montreal, 1884 (Dawson Brothers).—The coals and lignites of the Northwest Territory have been studied with great thoroughness by Mr. Hoffmann and with important results. The coal products are divided into Lignites, Lignite Coals and Coals, and the three groups are separately considered. The *Lignites* rather easily fall to pieces on exposure, the hygroscopic water ranges from 10 to 17 per cent, and they all communicate a brownish-red color to a boiling solution of potash; and they are all non-coking, in no instance affording a coherent coke. The *Lignitic Coals* do not easily disintegrate on exposure, the hygroscopic water varies from 8 to 9 per cent, they act with potash like the above but with less deep color; and none yield a coherent coke. The *coals* are hard and firm, bearing transportation without serious waste by reduction to pure coal; they give but slight coloration to a solution of potash; they yield by fast coking a good coherent coke though not by slow coking; they contain but a small proportion of hygroscopic water; and in general appearance and chemical com-

position resemble some varieties of coal of the Carboniferous system.

2. *Why are there no Fossils in the strata preceding the Cambrian?*—This question is answered, in the Proceedings of the Philadelphia Academy of Natural Sciences, by Mr. Charles Morris, by the suggestion that the earliest animals like the youngest stage of animal life generally had no hard parts to preserve; and that the sudden appearance of tribes was simply the appearance of species having hard or stony secretions. One difficulty in the way of the theory is presented by the existence of limestone formations of great extent in the Archæan which most geologists suppose to be of organic origin, and the existence also of phosphate of lime in large quantities which also is material of possible organic origin. These facts, although of uncertain bearing, throw doubts into all speculations on the subject.

3. *Cone-in-Cone Structure.*—Mr. John Young in a paper read before the Geological Society of Glasgow (Geol. Mag., June, 1885), arrives at the conclusion that the cone-in-cone structure, common in certain fine-grained sedimentary strata, consisting chiefly of calcareous material, clay and iron, is due to the upward escape of some gas generated in the deposit while it was in process of formation, each ebullition of gas producing a new layer. The cone is invariably found with the apex downward, and the author states that between the successive layers there is always a thin film of clay and also an axis of clay to the cone. The transverse wrinkling on the layers is attributed to a creeping downward of the plastic material through gravity. In the Scottish coalfield the structure occurs in strata of freshwater or lacustrine origin.

4. *Aerial formations.*—As the löss of China and similar deposits of other countries have been supposed to be of aerial or "Eolian" origin, the following facts from the Records of the Geological Survey of India, vol. xviii, p. 517, 1885, are interesting, as they illustrate the general truth that deposits so made never have for long distances a flat horizontal surface or horizontal stratification. "Aerial formations in the shape of blown sand cover large tracts in these wide valleys (in Beluchistan), and practically all the level country between Nushki and Helmund is covered with *sand-hills.* It is characteristic of them that they generally form low hills of crescent shape, with the horns and the scarp to leeward; the inclined plane formed by the currents of air are therefore generally dipping westward and show a rippled surface, resembling closely the accumulations of drift snow on the Himalayas."

5. *Irish and Canadian Rocks compared.*—In a paper by Mr. G. H. Kinahan, in the Geological Magazine for April, 1885, the characters of some Irish and Canadian Archæan rocks are discussed. He concludes that some of the gneissic Canadian rocks are very similar to Irish metamorphic rocks that are not Archæan but of different later periods, as Cambrian and Lower Silurian.

6. *Cambrian or Primordial rocks in the eastern part of British Columbia.*—Mr. H. H. WINWOOD describes, in the Geological Magazine for May, greenish micaceous, more or less calcareous rocks, containing remains of Paradoxides, Conocoryphe, and other allied forms, from a locality near Stephen, on the Canadian Pacific Railway, between the 116th and 117th meridians west of Greenwich.

7. *The folds in the Alps.*—The double folds described from the "Alpes Glaronnaises" by M. HEIM have been a subject of much discussion, and one of those objecting to them, M. Vacek, has a paper in the Jahrb. der k. k. Geol. Reichsanst., xxxiv, 234, 1884. M. Bertrand has a paper bearing on the same subject in the Bull. Soc. Geol. de France, xii, 318, 1884.—*Archives Sci. Phys. et Nat.*, xiii, March 15, 1885.

8. *Disintegration in the Alps.*—M. A. BRUN, after a microscopic study of the rocky crests of the Alps (Echo des Alpes, 1884), observes that they are penetrated with small fissures, leptoclases (joints) or microclases, having directions determined by the dislocations of the rock; that a mountain mass, like the Aiguille du Midi, in the Mt. Blanc chain, is traversed in certain directions by diaclases and paraclases—intersecting fissures, which divide the mountain into gigantic fragments, and were due to the pressures and tensions undergone by the rock since its formation. The microclases give the rock great porosity, permitting the absorption of water, which acts by corrosion as well as in other ways. The water charged with lime (from calcareous material in the granite) may contain even *three* milligrams of silica per liter.—*Archives Sci. et Phys. et Nat.*, xiii, March 15, 1885.

9. *The Amblypoda;* by E. D. COPE.—The American Naturalist for November and December, 1884, and January, 1885, contains an illustrated memoir by Professor Cope on species of the genera Coryphodon, Bathmodon, Pantolambda, Bathyopsis, Loxolophodon and Uintatherium.

10. *The Lenape Stone, or the Indian and the Mammoth;* by H. C. MERCER. 96 pp. 12mo, with illustrations. New York and London, 1885. (G. P. Putnam's Sons).—This little volume contains a review of the facts in Archæology bearing especially on the existence of man with the "Mammoth." The facts are well illustrated and appear to be fairly presented.

11. *United States Geological Survey.*—The following publications of the Survey have recently appeared:

Review of the Fossil Ostreidæ of North America and a comparison of the fossil with the living forms, by C. A. White, M.D., with appendices by Prof. A. Heilprin and Mr. John A. Ryder. From 4th Annual Report of the Director, 1882, 1883, Washington.

A Geological Reconnoissance in Southern Oregon, by Israel C. Russell. Ibid.

Bulletin of the Survey No. 10, on the Cambrian Faunas of North America. 56 pp., with 10 plates. Washington.

Bulletin No. 11, on the Quaternary and recent Mollusca of the Great Basin, by R. Ellsworth Call, introduced by a sketch of the Quaternary Lakes of the Great Basin, by G. K. Gilbert.

12. *Beiträge zur Kenntniss der Flora der Vorwelt, Band II.* Die Carbon-Flora der Schatzlarer Schichten, von D. Stur. K. K. Geol. Reichs. xi Band, I. Abtheilung.—With many lithographic plates and 48 zincotpyes. A grand work.

13. *Physikalische Krystallographie und Einleitung in die krystallographische Kenntniss der wichtigeren Substanzen* von PAUL GROTH. Zweite umgearbeitete und vermehrte Auflage, 710 pp. 8vo. Leipzig, 1885, (Wm. Engelmann).—This is a work which should be in the hands of every student not only of Mineralogy but of Chemistry also. The author is one of the most successful teachers in Germany, and his book is especially adapted, both in fulness of explanation and clearness of style, for the use of students. The new edition contains much new matter, more especially in regard to the description and use of the instruments employed in investigating the form and physical properties of crystallized substances. The chapter devoted to this subject extends to 130 pages and is all that could be desired, whether as regards the completeness of description or the abundance of illustrations.

14. *On the occurrence of native Silver in New Jersey;* by NELSON H. DARTON. (Communicated.)—The only locality in which metallic silver has been found in New Jersey hitherto is the Bridgewater copper mine, near Somerville, where it occasionally occurs as minute linings or blotches on the cuprite. Rogers called attention to this in his 1836 Report, in describing, for the first time, the copper deposits in the Mesozoic rocks of the State. Many of the copper ores from other parts of the formation have yielded small amounts of silver by assay, as noted by Schæffer.* Recently a small opening for copper ore has been made on the Westlake property, near the old Schuyler mine in Hudson County, and in cavities in the very rich chalcocite ore the writer found some very fine specimens, with thread silver associated with mammillary coatings of malachite. The ore occurs in red sandrock, adjacent to a dike of the trap sheet of the Hackensack upland and interbedded with carbonaceous strata, seamed with veins of anthracite of small size. These features I will describe in detail, in a memoir soon to appear.

The thread silver is easily identified, fusing readily to a bead, soluble in HNO_3, from which it precipitate as chloride with HCl. The threads are from 3^{mm} to 8^{mm} in length, and very uniformly about $\frac{1}{2}^{mm}$ in thickness; they are thinly coated with malachite, and when this is removed, are bright and crystalline in appearance; their regularity is sometimes interrupted by slight local thickenings, and the terminations are irregular and ragged. Several endeavors were made to cut sections for microscopic study, but without success. The threads are always separate from each other, extending from the walls out into the cavity. Assays of the average ore yielded about $12 per ton of silver and a trace of gold. The pocket was cleaned entirely out and the ore sent to Bergen Point.

* Eng. and Mining Jour., xxxiii, p. 90, 1882.

Careful examinations of the accessible portions of the Schuyler mine have never resulted in the discovery of thread silver. Metallic copper was found, however, in the Passaic mine in the same vicinity.

Laboratory, 112 Water St., New York City.

15. *On the Vanadates and Iodyrite from Lake Valley, Sierra County, New Mexico;* by F. A. GENTH and G. VOM RATH.—This interesting paper contains descriptions of vanadinite from the Sierra Bella and Sierra Grande mines, of endlichite, a vanadiferous mimetite, and of fine crystals of descloizite. The mineral called endlichite, after Dr. F. M. Endlich, superintendent of the Sierra Mines, is a sub-species intermediate between vanadinite and minetite. It occurs in crystalline groups with columnar structure sometimes radiating, also sheaf-like; the hexagonal form, characteristic of the group, is frequently distinct. The color varies from white to yellowish white or straw-yellow. The two analyses by Dr. Genth, proved that the vanadium and arsenic were present in the ratio of 1 : 1. One of these gave, after deducting impurities, and recalculating to 100:

As_2O_5	V_2O_5	Cl	PbO
10·73	7·94	2·18	79·15 = 100·00

The crystals of descloizite are exceptionally fine for the species. They include minute crystals mostly of a red to reddish-brown color, generally united in groups or forming incrustations; also a larger variety up to 8^{mm} in diameter and brownish-black to black in color. The former are octahedral, the latter rather prismatic in habit. Careful measurements by vom Rath go to prove that the species is orthorhombic in form, not monoclinic as made out by Websky. Several analyses of the different varieties conform to the generally accepted formula for the species, analogous to those of adamite, libethenite and olivenite. Iodyrite also occurs with the vanadates at the Sierra Grande mine in sulphur-yellow hexagonal crystals, or in crystalline masses.—*Amer. Philosoph. Soc.*, April 17, 1885.

16. *Hardness of the Diamond.*—At a recent meeting of the New York Academy of Sciences, Mr. G. F. Kunz called attention to some experiments made by the Messrs. Tiffany upon a diamond of extreme hardness. In the rough state it had a rounded form and was of composite crystallization ("round bort").

It had been cut into the rude outline form of a brilliant, and its table had been placed on a diamond polishing wheel for 100 days. The average circumference of that part of the wheel on which it was placed being about 2½ feet, and the wheel going at the rate of 2,800 revolutions per minute, the surface that traveled over the diamond table amounted to over 75,000 miles. At times, four and eight pounds were added to the usual 2¼ to 2½ pounds of the clamp or holder, and for a time forty pounds extra were added, this last causing the wheel to throw out scintillations for several

feet. The diamond fairly ploughed the wheel, practically ruining it, so that it required planing before it could be further used. No polish was produced, however, sufficient to give the brilliancy necessary in any diamond gem.

17. *A transparent crystal of Microlite;* by W. E. HIDDEN. (Communicated.)—The crystal here described was found three years ago in the mica mine near Amelia Court House, Amelia county, Virginia, (see this Journal xxii, 82, and xxv, 335. This crystal weighed 0·877 gram and showed the planes *O*, 3-3, *i* and 1 about equally developed. It differed from others found at the locality in its hyacinth-red color, in its perfect transparency and high specific gravity, viz: 6·13. Dunnington obtained for the Amelia microlite 5·66, Shepard for that of Chesterfield 5·56, and Nordenskjöld for Utö crystals 5·25. The high specific gravity of the crystal now described suggests that it may consist more largely of calcium tantalate and less of the columbate than the others that have been examined. The perfect transparency and freedom from flaws prompted me to send this specimen to the lapidary. The result was a gem which had all the brilliancy and beauty of a fine hyacinth, or of an essonite garnet.

I might also add that the cabinet of Mr. C. S. Bement of Philadelphia contains some pyrope-colored microlites from the same locality of nearly one centimeter diameter, embedded in smoky quartz; they are transparent in part and have highly polished planes. They were at first, not unnaturally, mistaken for garnets by the finders.

18. *Emeralds from North Carolina.*—Mr. J. A. D. Stephenson of Statesville, N. C., in a recent letter to the editors, calls attention to the fact that the occurrence of emeralds in Alexander county, announced as a new discovery on page 250 of volume xxix of this Journal (March, 1885), was the same as that which had been already described on page 153 of volume xxvii (February, 1884).

19. *Uranium minerals in the Black Hills*—Mr. L. W. Stillwell mentions the finding of pitchblende and uranium mica (probably autunite), the latter as a thin incrustation, on Bald Mountain in the Black Hills, Dakota.

III. BOTANY AND ZOOLOGY.

1. *The Woods of the United States, with an account of their Structure, Qualities, and Uses;* by C. S. SARGENT. New York, D. Appleton & Co. 1885. pp. 283, 8vo.—A handy volume, prepared especially as a guide to the magnificent Jesup collection of wood in the American Museum of Natural History at New York. The matter is condensed from the author's volume on the forest wealth of the United States, forming the ninth volume of the Tenth U. S. Census, which was noticed in our March number. This compact and cheap volume should be useful far beyond its immediate design. A. G.

2. *Eucalyptographia: a descriptive Atlas of the Eucalypts of Australia and the adjoining Islands;* by Baron Ferd. von Mueller, K.C., M.G., & S. Melbourne, 1879–1884, 4to.—The tenth decade of this great work and the one hundred plates besides the accessory ones having now been completed, the indefatigable author here closes the volume, giving title page, dedicatoin to the Prince of Wales, some general remarks, a detailed character to the genus, a synoptical view of the species, a geographic schedule, and three indexes. But the undertaking is not yet completed to the author's satisfaction. Twenty or thirty species are yet to be illustrated, none of them common or of known economic importance, and several still obscure for want of sufficient material. These Baron Mueller proposes to illustrate in "at least two more decades;" and he contemplates even a revision of the main body of the work, and the incorporation of recently accrued material; so that a second volume may in time be looked for. The courage, perseverance, and public spirit of the author are much to be admired. What an immense amount of work he has already done for the Australian flora! A. G.

3. *Les Organismes Problématiques des Anciennes Mers;* par le Marquis de Saporta. Paris: Masson, 1884. pp. 93, tab. 13, imp. 4to.—This follows up the author's *Apropos des Algues Fossiles,* in an equally sumptuous volume, even more richly illustrated. Besides the 13 plates there is a double one serving as frontispiece, representing *Bilobites prendo-furcifera,* of the natural size of the specimen, and a good number of wood-cuts in the letter-press. Four of the plates illustrate fossilization in demi-relief of *Brachyphyllum* and *Nymphæa,* the others *Gyrolithes, Vexillum,* and *Bilobites,*—vestiges of problematical forms of primordial seas, which in the letter-press are elaborately expounded. He brings new evidence and considerations to show that these are really casts of organisms. A. G.

4. *The Lythraceæ of the United States;* by E. Koehne. Bot. Gazette for May, 1885, with a plate.—It is gratifying to have articles from European botanists of mark in our own journals, and Dr. Koehne (of Berlin and Friedenau) may first of all be complimented for his idiomatic English. It is well-known that he has made an exhaustive study of the *Lythraceæ,* the full results of which appear in his monograph of the order published in Engler's Botanische Jahrbucher. Although this order is feebly represented in this country, yet we have more genera and species than any other part of the northern temperate zone, and there was a good deal to be done for the elucidation both of genera and species. The present article summarily presents the result so far as affects North American botany, and its publication in Coulter's Botanical Gazette renders it accessible to those most interested.

As to the propriety of re-establishing the Linnæan genus *Rotala* (which Bentham had referred to *Ammannia*), we could not now give a valuable opinion. Dr. Koehne says that, "it will be rather difficult, I fear, to convince North American botanists of the

necessity of separating the genus *Rotala* from *Ammannia;* for, unfortunately, the only species met with in the United States (*A. ramosior L.*), has an Ammannia-like habit, which is not to be observed in the 31 other species of *Rotala.*" Our bias, accordingly is against the separation. The restoration of *Didiplis* to *Peplis* may be more readily acceded to. It may be hoped that the species of *Lythrum* are well discriminated, also the genera *Nesæa, Heimia,* and *Decodon.* But we must enter a protest against the making of a new name, *Cuphea petiolata*, Koehne, for *C. viscosissima*, Jacq. It legitimately follows from the Laws of Nomenclature which Dr. Koehne generally adopts, that no new name should be made when there is already a fit one, that the earliest name under the proper genus should stand, notwithstanding any older specific name under some other genus. This has been well argued by Bentham, and we supposed that the general practice was conforming to it. A. G.

5. *Monographie der Gattung Clematis von* Dr. Otto Kuntze (*Separatabzug aus den Verhandl. Botan. Vereins, Brandenburg*, xxvi.) Berlin, 1885, pp. 83–202, 8vo.—There are two opposite extremes of departure from the Linnæan idea of species which are exemplified in recent phytography. One is that of Gardoger, who multiplies the European Roses into a thousand and more of species. Of the other extreme Dr. Kuntze is a type. For instance, in the present elaborate essay, he reduces *Clematis Virginiana, ligusticifolia, Catesbeyana* and *Drummondii* to forms of *C. dioica;* also *C. reticulata* as well as *C. coccinea* to *C. Viorna*, adding moreover Lavallée's *C. Sargenti*, which belongs to *C. Pitcheri*, which again is referred to the *C. cordata* of Sims. Then, under the Old World *C. Viticella* he assembles *C. crispa* and *C. Walteri*, even under the same subspecies, and will still have it that the erroneous *C. crispa* of DeCandolle, which he well refers to his var. *Campaniflora* is North American as well as S. European. The only reason for so attributing it is that it has been cultivated under the false name of *C. crispa*, and the genuine *C. crispa* L. came from North America. Also *C. verticillaris* is referred to *C. alpina*, and *C. ochroleuca* as well as *C. Fremontii* to *C. integrifolia!* To compensate for which extraordinary unions, Dr. Kuntze has made a new species, *C. pseudo-atragene*, of part of the North American *C. alpina* of our botanists (with the habitats Oregon, Colorado, New York, Canada, and with a var. *pseudo-alpina* for Fendler's New Mexican specimens), while he gives us *C. alpina, typica* from Lyell's and Bourgeau's collections. A. G.

6. *Recherches Anatomiques sur les Organes Vegetatifs de l' Urtica dioica;* par A. Gravis, D.S. Nat., etc. Bruxelles, 1885. pp. 256, tab. 23, 4to.—One of the *Memoires courronnés* of the Royal Academy of Sciences of Belgium, a goodly volume, as it were, devoted to the anatomy of the vegetative organs of the common Nettle, thus taken as a basis for a general and comparative study of the *Urticaceæ*. This exhaustive work was done in the botanical laboratory of the faculty of sciences of the University of

Lille, under the direction of Prof. Bertrand, and in the new botanical institute of the University of Liége, directed by Prof. Morren. The intimate structure of stem, root and leaf is worked out and exemplified under all modifications attendant upon age, level and biological conditions, and the importance of recognizing these conditions and states is insisted on. This treatise would be an excellent *vade mecum* and guide for any student who wished to undertake serious work in vegetable histology. The style of exposition is as clear as are the illustrative figures. Perhaps this is because it is French. A. G.

7. The following Catalogues should also receive notice:

A Preliminary List of the Plants of New Brunswick: Compiled by Rev. James Fowler, M.A., now of Queen's College, Kingston, Ontario. Published at St. John, N. B., 1885.—The author has aimed "to exclude every species of which he had not seen a specimen"; and this gives a real value to this catalogue. Moreover, the ballast-deposit plants and those just escaping from gardens are wisely placed in a separate list. The author modestly calls his work a preliminary list, and in the title states that it was compiled "with assistance of members of the New Brunswick Natural History Society." He is one of the best and most conscientious botanists of the Dominion; and this list has particular interest in relation to the most northern limit attained by many United States species.

Check-list of North American Gamopetalæ from Gray's Synoptical Flora; by H. N. Patterson, editor and printer. Oquawka, Illinois.—We have neglected till now to notice this neatly executed pamphlet, which follows the same author's List of North American Polypetalæ, from Watson's Index. Mr. Patterson does all his work tastefully and well.

Check-list of North American Mosses and Hepaticæ; arranged from Mosses of North America by Lesquereux and James and the Descriptive Catalogue of Hepaticæ by Underwood; by Clara E. Cummings, Wellesley College. An indication of the increasing interest now taken in Mosses and their allies through the facilities supplied by the two works from which this list is compiled.

Catalogue of the Phœnogamous and Vascular Cryptogamous Plants of North America; by Dr. J. H. Oyster, Paola, Kansas. 1885.—This is also a check-list for convenience of botanists in making exchanges. The species are numbered in succession, and run up to 9,750. It is better in print and proof-reading than would be expected. There is evidently a considerable demand for such lists, and the supply now seems adequate to the occasion. A. G.

8. *Eggs of Echidna hystrix.*—The discoveries of Dr. Haacke and Mr. Caldwell are briefly mentioned in this Journal, vol. xxviii, 475, and xxix, 74. Dr. Haacke gives additional results in a communication of January 8, 1885, to the Royal Society of South Australia. He states that the egg was about 15^{mm} long

and 13^{mm} wide, and it had a parchment-like shell like that of many reptiles, which was $\frac{1}{2}^{mm}$ thick. He inclines to the opinion of Professor Gegenbaur (Morphologisches Jahrbuch, 1884), who examined two adult females of *Echidna setosa*, that the pouches are periodically developed; and that "the pouch attains its greatest development during the time it serves as incubator for the egg, and that it consists of a pair of semi-lunar fossæ during the period the mother suckles her progeny, disappearing afterwards altogether."

In the examination in September of two male Echidnæ he discovered "the unmistakable homologue of the mammary gland of the female." He found "in situations corresponding to those in the female, similar tufts of short hair quite as plain as those indicative of the mammary areolæ in the female;" and, on skinning the animals, the rudimentary mammary glands were without difficulty discovered. "In the largest of the two specimens the one mammary gland forms a mass about 8^{mm} long by 4^{mm} wide, the lobules being about 2^{mm} long. The other gland is a little larger. The glands are built after the same plan as the female glands, and contain a considerable number of lobules." Dr. Haacke adds: "In conclusion, I should not forget to mention that I am aware of Mr. W. H. Caldwell's discovery of the oviparity of the Monotremata, made about the same time as it seems at which my discovery was made, and that the British Association at their Montreal meeting received the information of Mr. Caldwell's discovery about the same date at which my *Echidna egg* was exhibited at a meeting of the Royal Society of South Australia. But this is all I know at present about Mr. Caldwell's discovery."

IV. Miscellaneous Scientific Intelligence.

1. *American Philosophical Society of Philadelphia.*—This society, whose first meeting was held in the year 1743, has published in a volume of 876 pages, the early correspondence and the minutes of the meetings, from the year 1744 to July, 1838, at which time the publication of the "Proceedings" heretofore printed, began. It is accompanied with copious indexes. The first letter with regard to the establishment of the society published in the volume is by Benjamin Franklin, bearing the date April 5, 1744, and a lithographic fac-simile of it makes a frontispiece to the volume. It states that "the society, as far as relates to Philadelphia, is actually formed, and has had several meetings to mutual satisfaction." The members, as stated in it, were "Dr. Thomas Bond, Mr. John Bartram, Botanist, Mr. Thomas Godfrey, Mathematician, Mr. Samuel Rhodes, Mechanician, Mr. Wm. Parsons, Geographer, Dr. Phineas Bond, General Natural Philosopher, Mr. Thomas Hopkinson, President, Mr. Wm. Coleman, Treasurer B. Franklin, Secretary," to whom others were later added. The expression "as far as relates to Philadelphia" is shown afterward to have implied that the original scheme in view was the

establishment of an "American Philosophical Society" with one of its component societies at Philadelphia. In January, 1768, the number of members was about fifty, and Mr. Winthrop of Massachusetts, Dr. Styles of Connecticut, Hon. Cadwalader Colden of New York, Dr. Lee of Virginia, and Dr. Garden of South Carolina were made Corresponding Members.

2. *American Association for the Advancement of Science.*—The next meeting of the American Association—the thirty-fourth—will be held in Ann Arbor, Michigan, beginning on Wednesday, 26th of August. The circular of the Local Committee states that the buildings and grounds of the University of Michigan will be placed at the disposal of the Association during the meeting. Arrangements are made for an excursion free of all expense to the Saginaw valley, and another, after the adjournment, to Detroit and Mackinack Island and return. The Secretary of the local committee of arrangements is Professor John W. Langley. Members who intend to be present are desired to inform the Secretary in advance as to the kind of accommodations they may prefer, in order that arrangements may be made accordingly. The Michigan Central Railroad will probably run a special train from Buffalo to Ann Arbor, leaving Buffalo, on Monday morning, August 25th, if a sufficient number of members signify their wish to avail themselves of it; and information on this point also should be sent to the secretary. This train will stop, if the party wish to do so, from one to two hours at the Falls View Station, Niagara Falls, "where ample facilities for visiting the Falls will be found."

The University offers its apparatus for any experimental illustrations that may require it, and will "furnish electricity either from a dynamo, from a storage battery, or from primary batteries as may be needed by members reading papers on electrical subjects.

3. *Meteorological Circular Letter.*—For the following circular letter, this Journal is indebted to General Hazen, to whom it was addressed by the International Committee of Meteorology, St. Petersburg and London, May 1, 1885:—

In compliance with the instructions of the International Congress on Meteorology at Rome, we have the honor to inform you that the International Committee on Meteorology instituted by this congress will meet for a third session in Paris in the beginning of the coming September and that up to the present time the following questions have been proposed for consideration during this session:

(1) Report of the Secretary on the labors of the Committee since the meeting at Copenhagen.

(2) Report of Messrs. Brito Capello, Hildebrandsson and Ley on the observation of the cirrus.

(3) Does it seem opportune to soon convene a third international congress of Meteorologists?

(4) Establishment of stations of the first order on the Congo.

(5) Discussion on the utility of the summaries of the state of the weather as

published in the different countries, and eventual preparation of plan for more uniformity.

(6) Discussion of the utility on the meteorological telegrams from America proposed by Mr. (General) Hazen, and of an eventual organization for their distribution in Europe.

(7) By what means can the timely receipt of meteorological telegrams be assured?

(8) Should the reduction of barometer readings to gravity under 45° latitude be generally introduced?

(9) Is it desirable to count also in Meteorology the hours of the day from 1^h up to 24^h in accordance with the resolutions of the international conference in Washington?

(10) Designation for a uniformly covered sky according to the form of the clouds.

(11) Definition of rain and snow days.

(12) Should not the general adoption of a uniform height above the earth for rain-gauges be recommended?

(13) What progress has been made lately in the more exact measurement of snow?

(14) International Meteorological tables.

(15) Modification of the rules for the administration of the International Committee.

In case you intend to submit to the Committee remarks on one or the other of these questions we request that you will please address them in good time to Mr. Robert H. Scott, (Meteorological Office, 116 Victoria street, London).

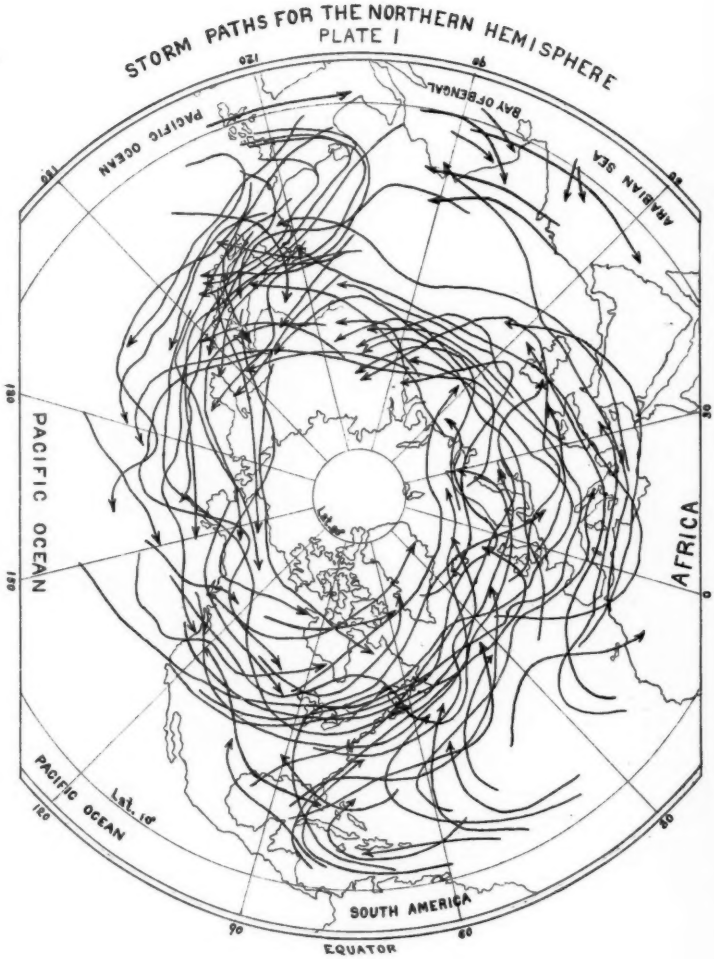
For the International Committee on Meteorology.

(Signed) N. Wild, Pres., R. H. Scott, Sec.

4. *Digestion Experiments.* Note to the Editors by H. P. Armsby.—After the proof of my article on Digestion Experiments in the May number of this Journal (p. 355, vol. xxix) had left my hands, my attention was called to the fact that Dr. E. Lewis Sturtevant, Director of the New York Agricultural Experiment Station, had published a preliminary account of digestion experiments made at that institution about a year previously, and about a month before the first account of my own experiment was printed. The opening sentences of my article should therefore be modified in accordance with this fact.

5. *A Catalogue of Chemical Periodicals;* by H. Carrington Bolton, Ph.D., Prof. Chem. Trinity College, Hartford, Conn.—This valuable catalogue by Professor Bolton is published in vol. iii of the Annals of the New York Academy of Sciences, pages 159 to 216. The same number of the Annals contains a paper by Albert R. Leeds, on the literature of ozone and peroxide of hydrogen, and by G. N. Lawrence on new species of birds of the Families Tyrannidæ, Cypselidæ and Columbidæ.

6. *When did Life Begin;* a monograph by G. Hilton Scribner. 64 pp. 8vo. New York, 1883. (Charles Scribner's Sons).—*Paradise Found*, by Wm. F. Warren, President of Boston University. Third edition, 496 pp. 8vo. Boston, 1885. (Houghton, Mifflin & Co.)—The first of these works aims to show that life, the earliest and latest, began in the Arctic region. The latter sustains the polar origin of man. Both are too far within the realms of speculation for further notice in this place.



Julius Bien & Co. Photo Lith.